HEWLETT-PACKARD III (A)

Drill Jig Design for a Structural Plate

At Hewlett-Packard Company, tool engineers must often design or modify the machinery to be used in the manufacture of their products. A job frequently given to a tool engineer is that of designing a drill jig[1] for a new instrument component. Such a design problem recently faced tool engineers in the Microwave Division of Hewlett-Packard. A drill jig was needed for drilling holes in a small sand cast plate used in a new instrument.

Founded in 1939, Hewlett-Packard has grown from a two-man company to an organization regarded as the world's largest producer of electronic test equipment. They manufacture a complete line of electronic and microwave test instrumentation, including oscilloscopes, audio generators, power meters, electronic counters, and a complete array of waveguide equipment. The company now employs over 6,000 people and has an annual sales volume of over $100 million. Although the main office is located in Palo Alto, California, manufacturing plants are also located throughout the United States, in England, Germany, and Japan. The company maintains sales and service offices in nearly every major city of the free world.

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1) Drill Jig - a device for holding a part during drilling.

Prepared in the Design Division, Department of Mechanical Engineering, Stanford University by Eugene Echterling, under the direction of Professor Peter Z. Bulkeley with support from the National Science Foundation. The cooperation of Carl Buchass and Ronald Gross of the Hewlett-Packard Company is gratefully acknowledged.

New Signal Generator

One of Hewlett-Packard's newest instruments is the Model 8614A Signal Generator. This signal generator is used to generate electrical signals ranging from 800 megacycles/second to 2400 megacycles/second.[1] Signals with various forms such as pulse, square wave, or sine wave may be selected. Such a device is used by electronic technicians to test communication equipment aboard ships, airplanes, and satellites. The accurate monitoring of both frequency and power of the signal makes the Model 8614A a useful instrument for measuring such properties as transmission line characteristics,[2] VHF receiver sensitivity,[3] and amplifier gain.[4]

This generator converts electrical energy of electron flow into radiant energy of an electromagnetic wave and provides for regulating both power and frequency of the wave. In a reflex klystron tube within the instrument, an electron gun (consisting of a heated cathode button and a focusing ring) supplies a constant beam of electrons. This constant beam is changed into a varying current of electrons by a process called electron bunching. In the bunching process, a small input voltage alternately decreases and increases the velocity of the electrons in the constant current beam forming an electron velocity pattern which is similar to the input voltage pattern. A portion of the electron beam slows down or speeds up depending upon the direction and strength of the input signal. After accelerating or decelerating at the input gap, the electrons drift toward a negatively charged repeller which turns the electron stream around 180°. The stream of electrons then continues to drift back through the input gap, which serves as the output gap for the inverted stream. The small changes of velocity introduced by the input gap permit the electrons with higher than average velocity to overtake the electrons with lower than average velocity. This bunching process occurs as the electrons cross the drift space. As a result, the electron beam is converted from a uniform current to a bunched or pulsating current. At the gap, the energy of the returning pulsating current is converted into the electromagnetic energy of a generated wave having the form of the original input signal. This is accomplished by a negative field which slows the electron stream down, taking kinetic energy from the flow of electrons.

A cavity resonator is used in the 8614A to control the frequency of the generated signal. The action of the resonator is analogous to the function of a slide in a slide trombone, with the electromagnetic field being analogous to the sound wave. The resonator is a metallic cavity, resonant at specific frequencies determined by the dimensions of the cavity and the electric field within it. The cavity is the space between a center conductor and the wall of a hole

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1) 1 Megacycle/second = 1,000,000 cycles/second.

2) Transmission Line Characteristics - Data which describes voltage and current behavior of transmitting systems under various conditions of load.

3) VHF Receiver Sensitivity - That characteristic of a VHF receiver which determines the minimum strength of signal input capable of causing a desired value of signal output.

4) Amplifier Gain - Ratio of output signal to input signal.

in the cavity housing (Figure 1). At one end of the cavity is the klystron tube. At the other end is a movable plunger consisting of a plastic ring with metallic fingers which contact both the wall of the center conductor and the wall of the cavity housing. As the plunger is moved to shorten or lengthen the cavity, the frequency of the generated signal is changed. For high frequencies the cavity is shortened; for low frequencies the cavity is lengthened. The total backlash in the system between the panel readout and the plunger must not cause more than 5 megacycles error across the bandwidth of 800 to 2400 megacycles. The corresponding positional tolerance on the plunger is ± .0005 inches.

The plunger is held by a movable carriage riding on two guide posts (Figures 2,3,4,5). The guide posts press fit (Exhibit A-1) into holes reamed in the cavity housing. Proper alignment of the two guide posts is dependent upon parallelism of the two reamed holes in the cavity housing. The rods extend through the cast carriage housing, passing through its open center and clearance holes in its ends.

The projecting ends of the guide posts are held by a small drilled plate which is screwed to the side frame of the instrument. The plate is purely a structural member. It serves no function other than mechanical support. It is for properly aligning the cavity structure with respect to the front panel of the instrument, where the frequency selection knob is located. Turning the frequency selection knob rotates a pinion gear[1] which drives the rack gear[2] attached to the carriage. This moves the plunger and changes the frequency of the signal. The carriage, and hence the plunger, travels approximately two and one-half inches.

The most important locational tolerances on the end plate are those associated with the holes drilled in the two bosses. Since these holes must be aligned with the ends of the guide posts, they have a tolerance of ± .002 inches for each dimension. This tolerance is the same as the tolerance on the reamed post holes in the cavity housing. The engineers assumed this tolerance would prevent binding of the carriage on the guide posts. Choice of a ± .005 inch tolerance for the tapped mounting holes was explained by a Hewlett-Packard engineer thus: "We have found that plus or minus five-thousandths of an inch is a reasonable average tolerance for most of the mating parts of our instruments. As a result, we have printed on our drawings a note to the effect that all dimensions given in decimals are to be plus or minus five-thousandths of an inch, unless otherwise noted."

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1) Pinion - Of two gears that run together, the one with the smaller number of teeth.

2) Rack - A gear with teeth spaced along a straight line, suitable for straight-line motion.

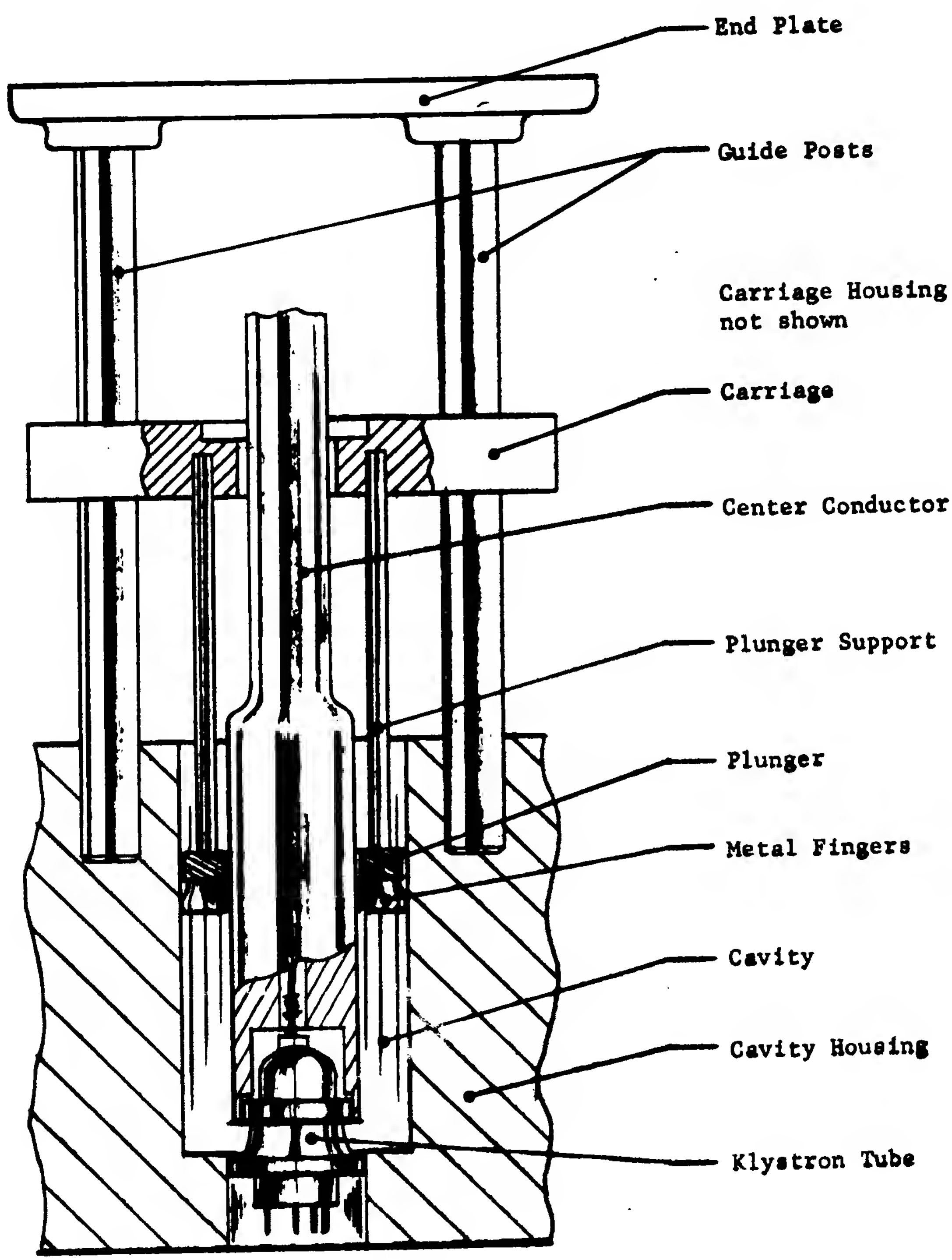

Figure 1 - Schematic diagram of cavity configuration.
(Driving mechanism not shown.)

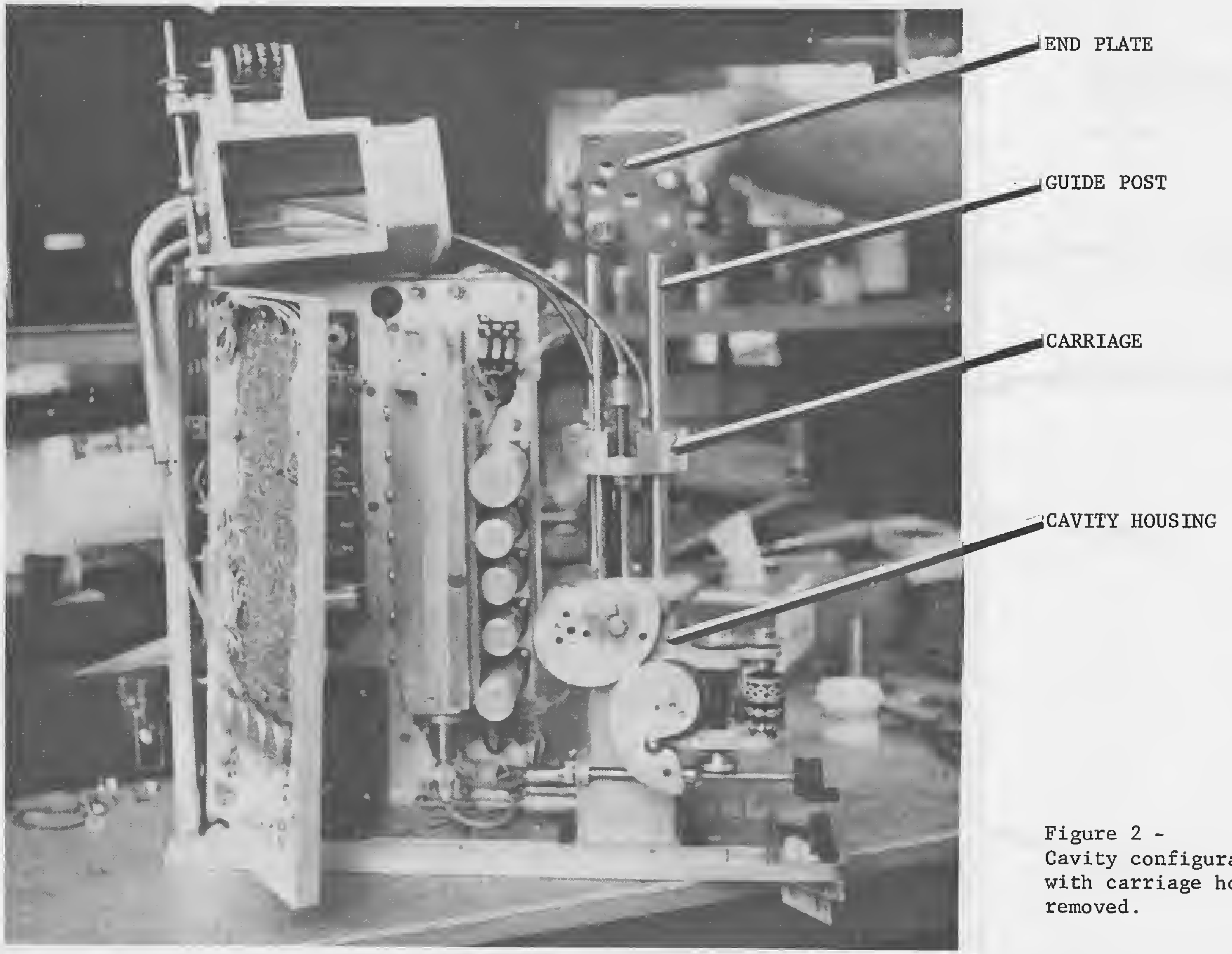

Figure 2 -
Cavity configuration with carriage housing removed.

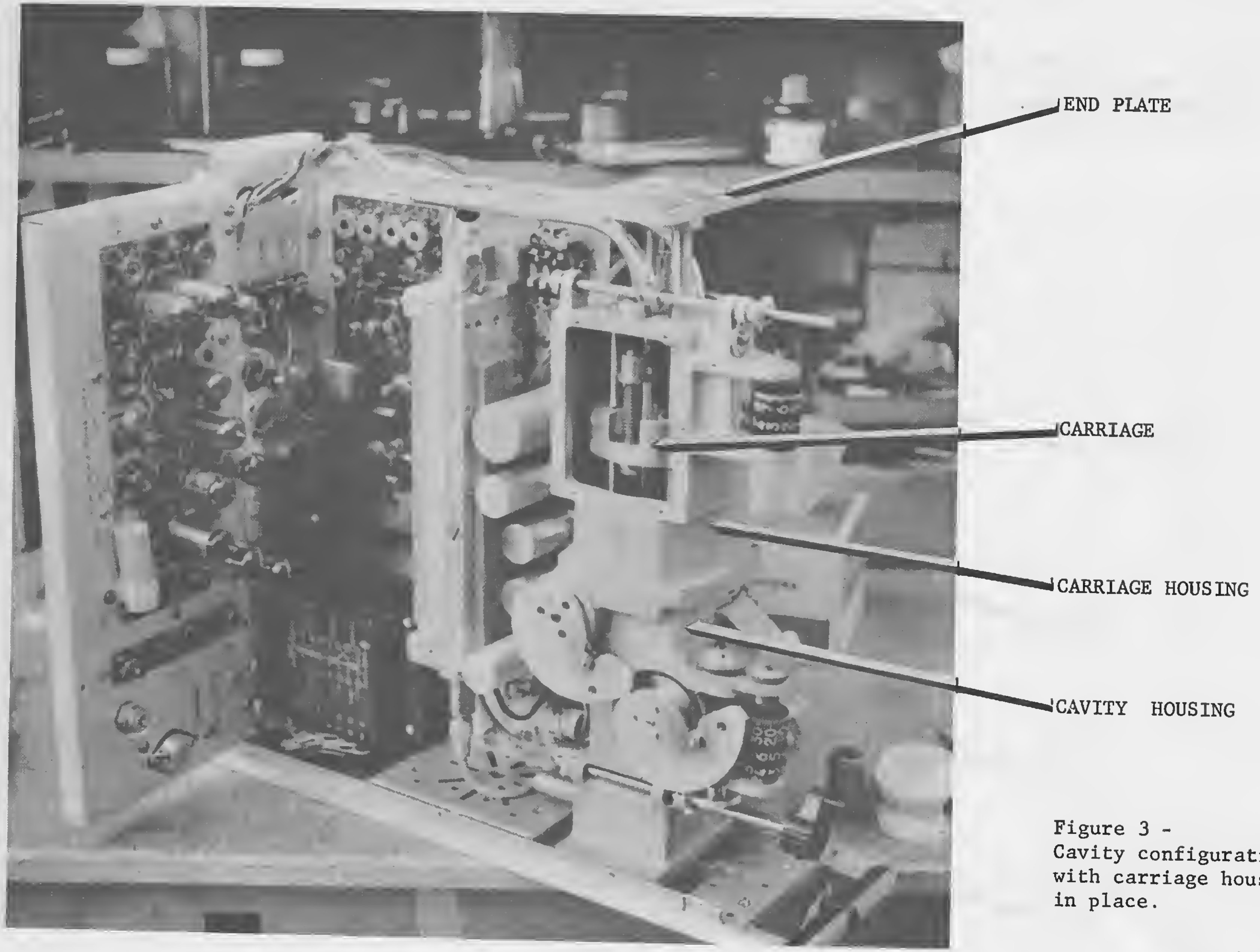

Figure 3 -
Cavity configuration
with carriage housing
in place.

FIGURE 4 - INSTRUMENT WITH SIDE FRAME REMOVED, SHOWING END PLATE

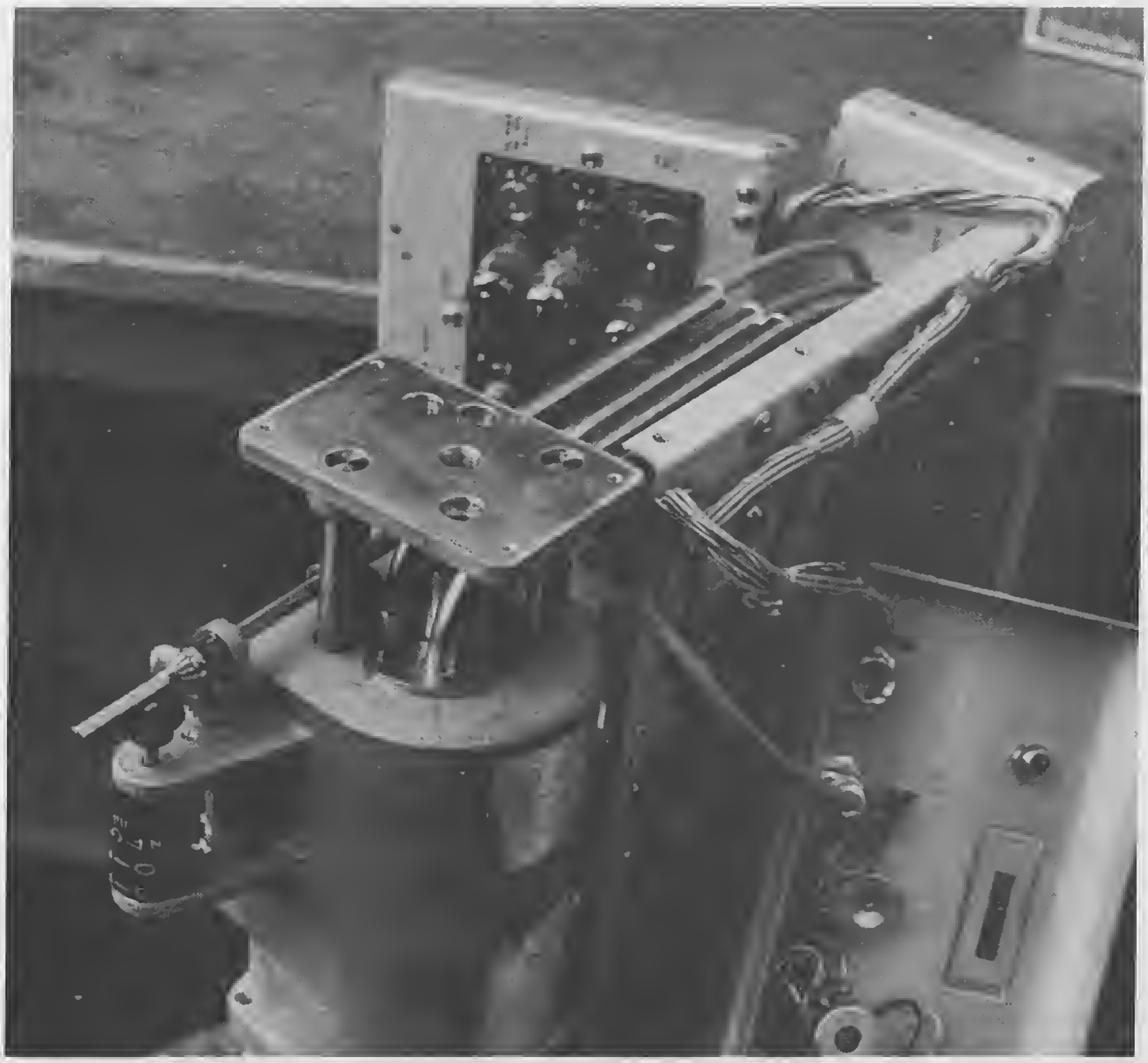

FIGURE 5 - END PLATE AND CARRIAGE HOUSING

The remaining four holes are only for clearance[1] and do not have critical size or locational tolerances. One of the clearance holes is for the moving rod which holds the carriage assembly and driving rack. The other three clearance holes are for inserting long screwdrivers and allen wrenches into the carriage housing when adjusting the instrument prior to shipment.

The end plate consists of an aluminum sand casting with two bosses[2] on one side (Figure 6). Hewlett-Packard purchases the part as a rough casting from a foundry in Palo Alto. All machining operations are performed in Hewlett-Packard production shops.

The first operation on the casting is machining the large, flat surface. This is normally done on a belt sander. However, recently purchased castings have been too thick for this to be done economically. This has necessitated the use of a fly cutter on a vertical milling machine (Figures 7-11). The tool engineer commented on this operation, "On the part drawing (Exhibit A-2) the large flat surface is shown as a finished surface. For a surface which is to be finish machined, the foundry will allow 1/16" of extra metal to be removed by the machining process. Also, in this particular case the foundry chose to gate[3] into this surface. Gates are subsequently sawed off and sanded at the foundry. This also leaves a little extra metal projecting from the face of the casting. When we receive the castings, they are still rough where the gates were sanded off. Since this is the surface which mounts against the side frame of the instrument, we have to machine it. Had the casting been gated somewhere else, we could have left this surface in the as-cast condition." For the milling operation, no special mounting fixture is used. The part is simply clamped in a mill vise bolted to the bed of the mill (Figure 9).

After milling, the parts are sent to the drilling department for completion of machining. Drilling is done on a Burgemaster turret drill having six stations (Figures 12-14). Four drill stations are

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1 Clearance - An open space allowing for non-contacting adjacent parts.

2 Boss - Raised portion of a casting which provides material for threading, etc.

3 Gate - An opening in the sand mold through which the molten metal flows

FIGURE 6 - MACHINED END PLATE

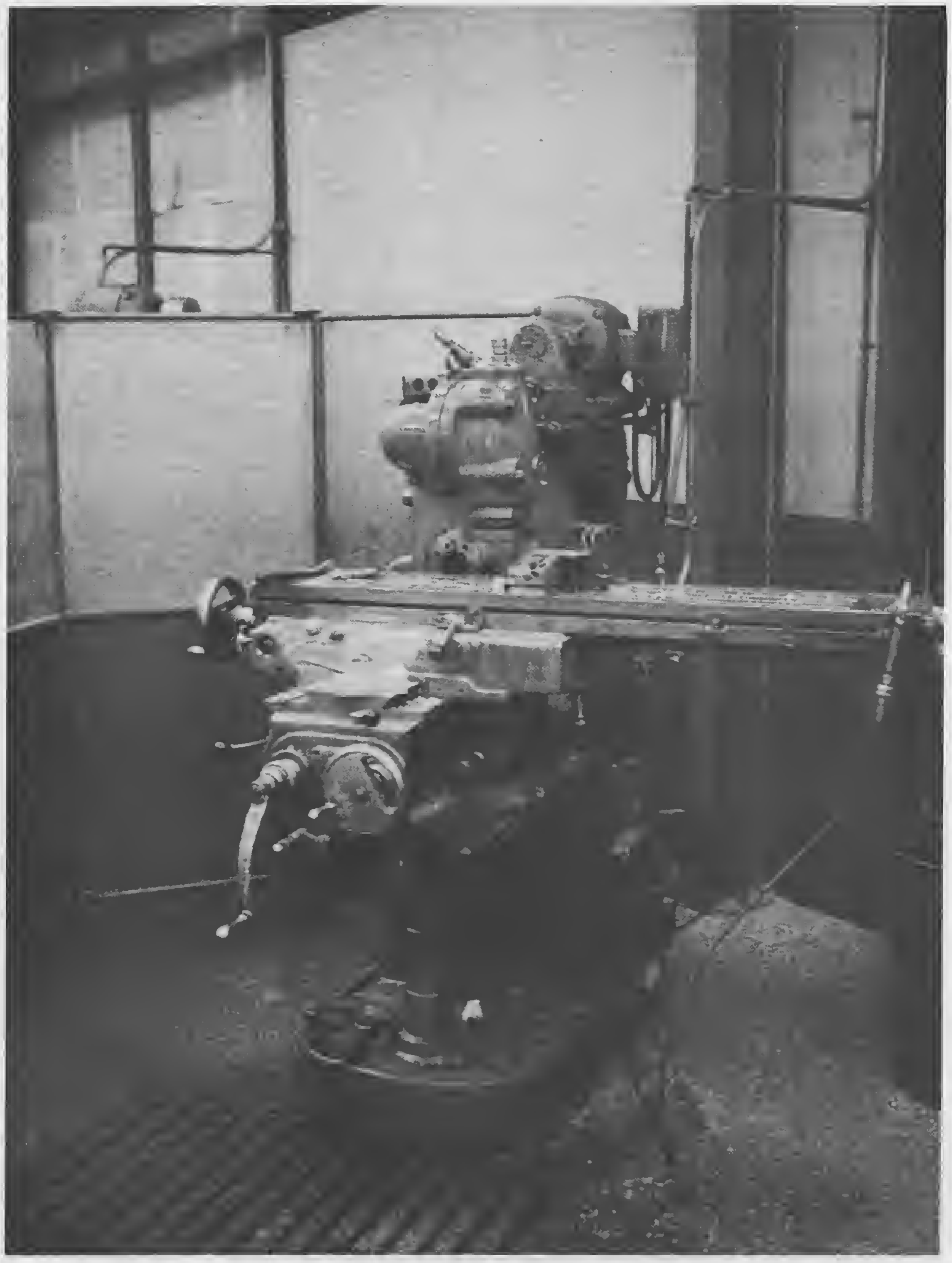

FIGURE 7 - VERTICAL MILLING MACHINE SHOWN MILLING THE LARGE FLAT SURFACE OF THE CASTING

FIGURE 8 - CASTINGS READY FOR MILLING

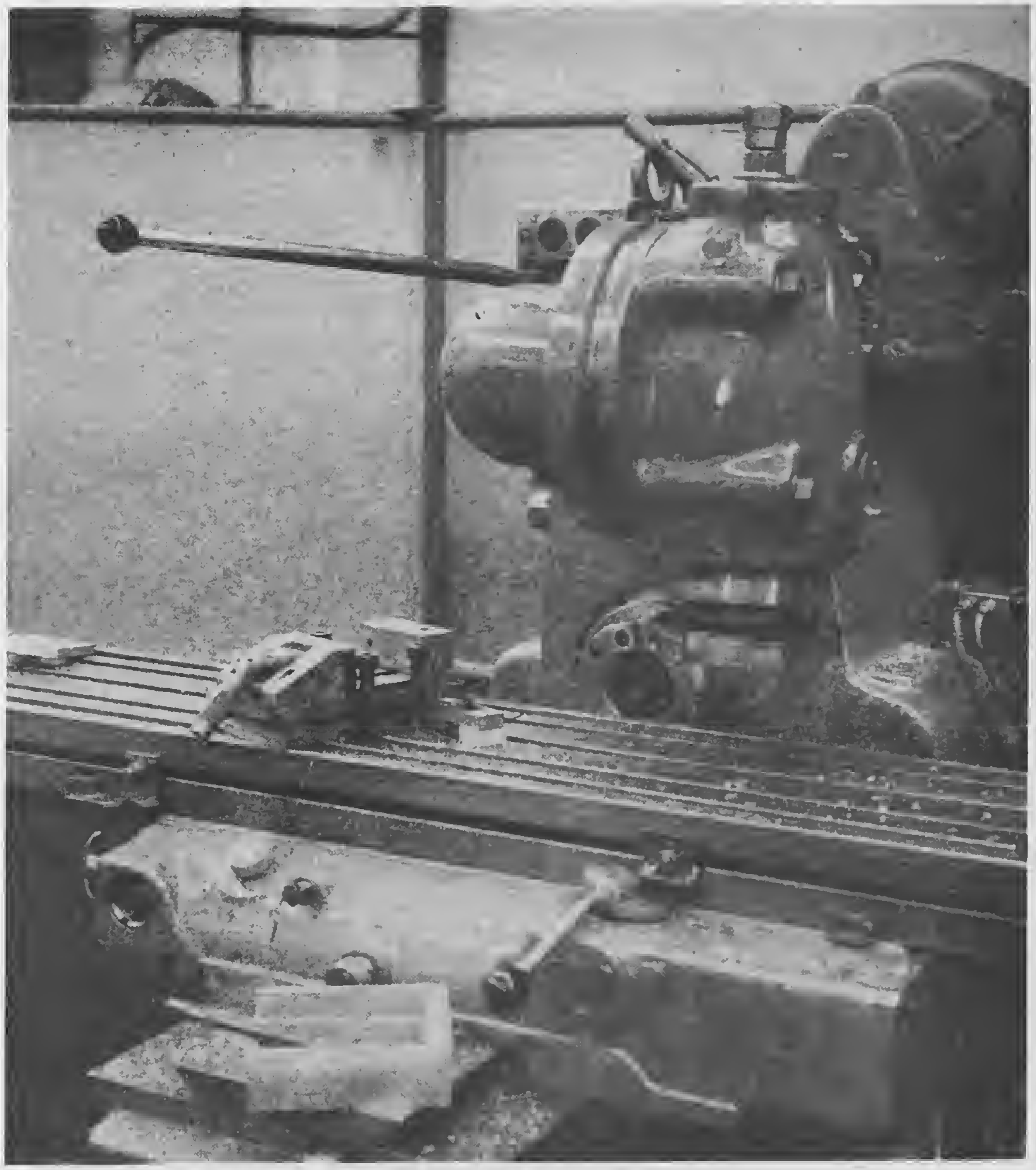

FIGURE 9 - VISE FOR HOLDING CASTING DURING MILLING

FIGURE 10 - MACHINIST LOADING THE CASTING IN THE MILLING VISE

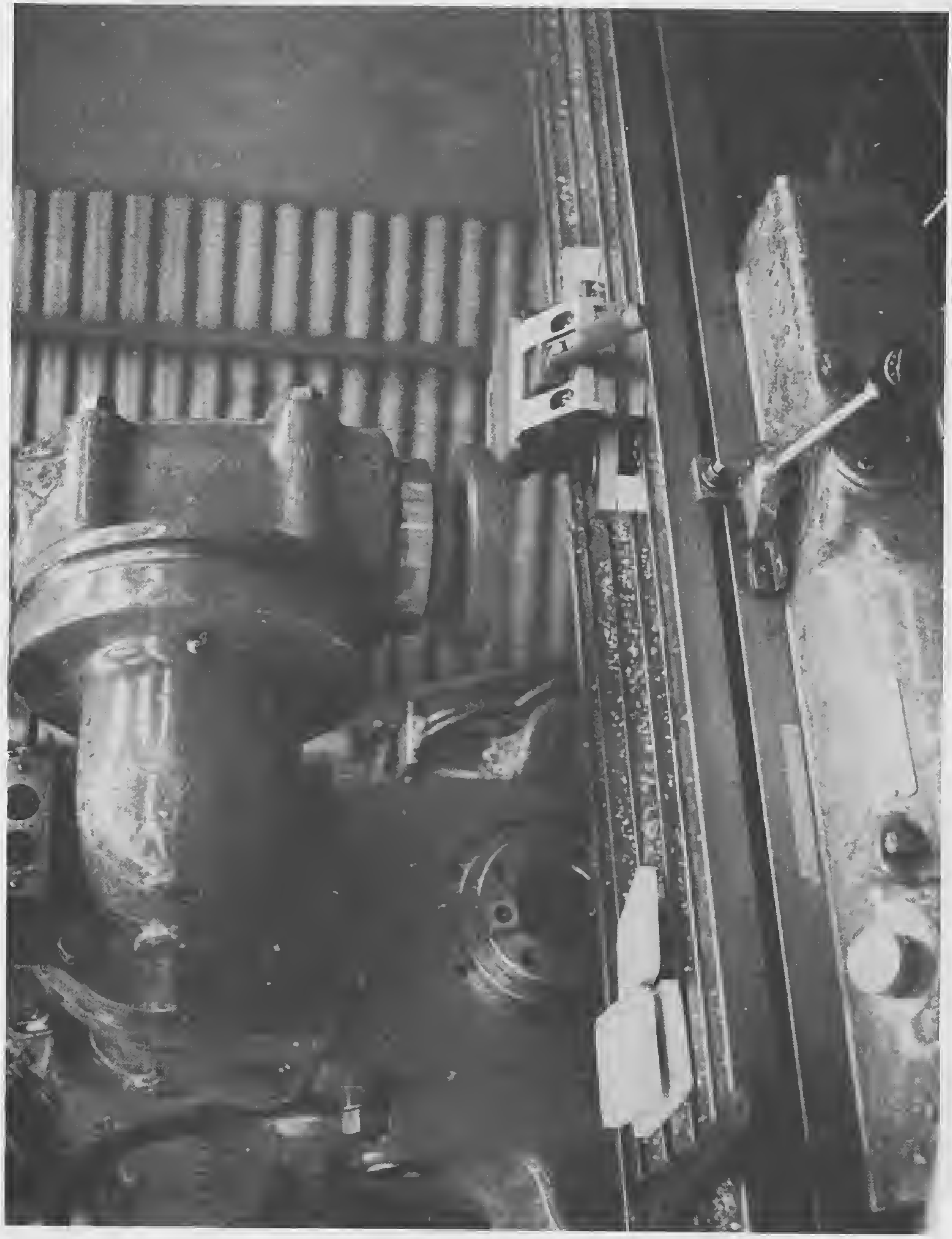

FIGURE 11 - MILLING OPERATION NEAR COMPLETION
(MILL BED MOVES FROM LEFT TO RIGHT)

FIGURE 12 - TURRET DRILL (VIEW A)

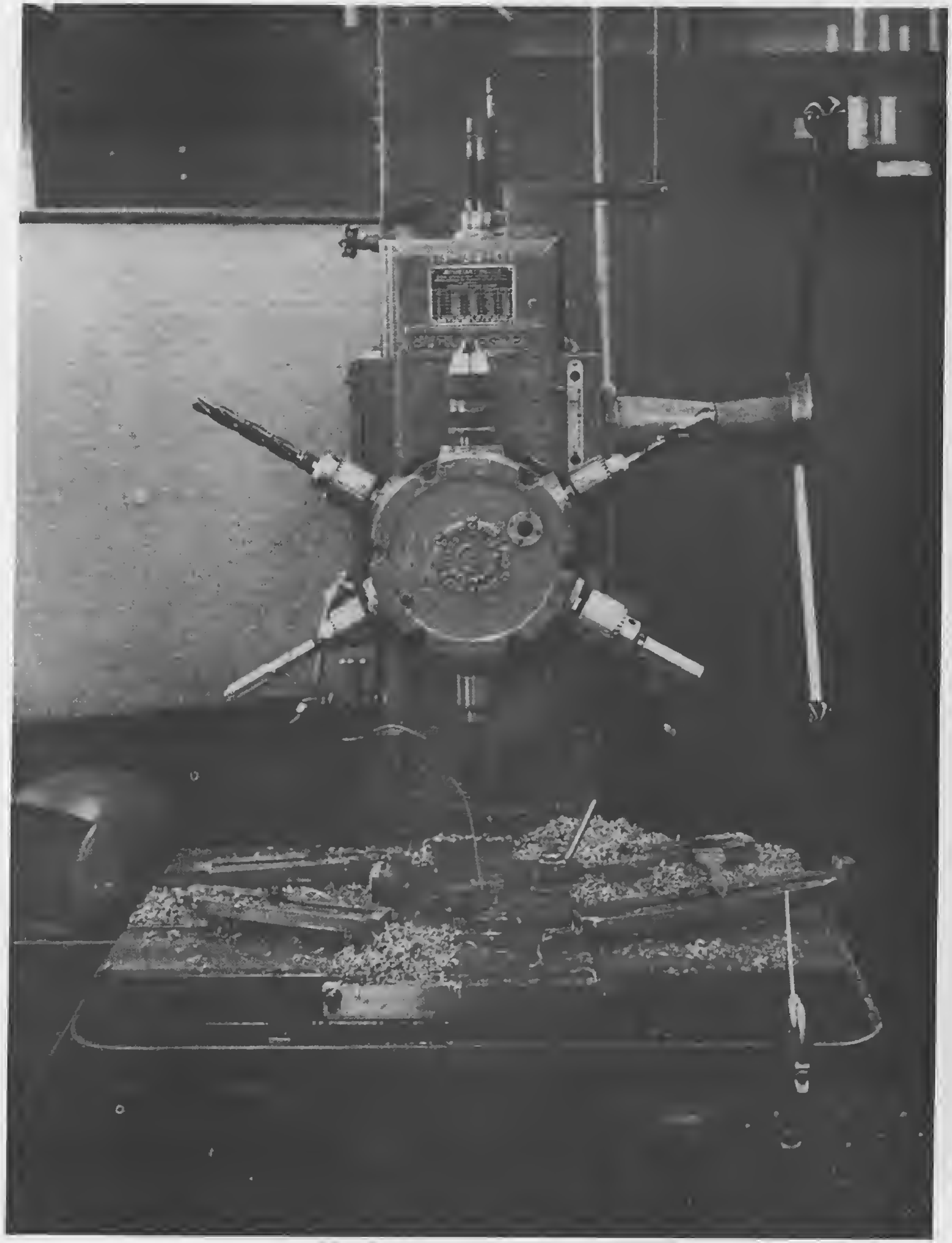

FIGURE 13 - TURRET DRILL (VIEW B)

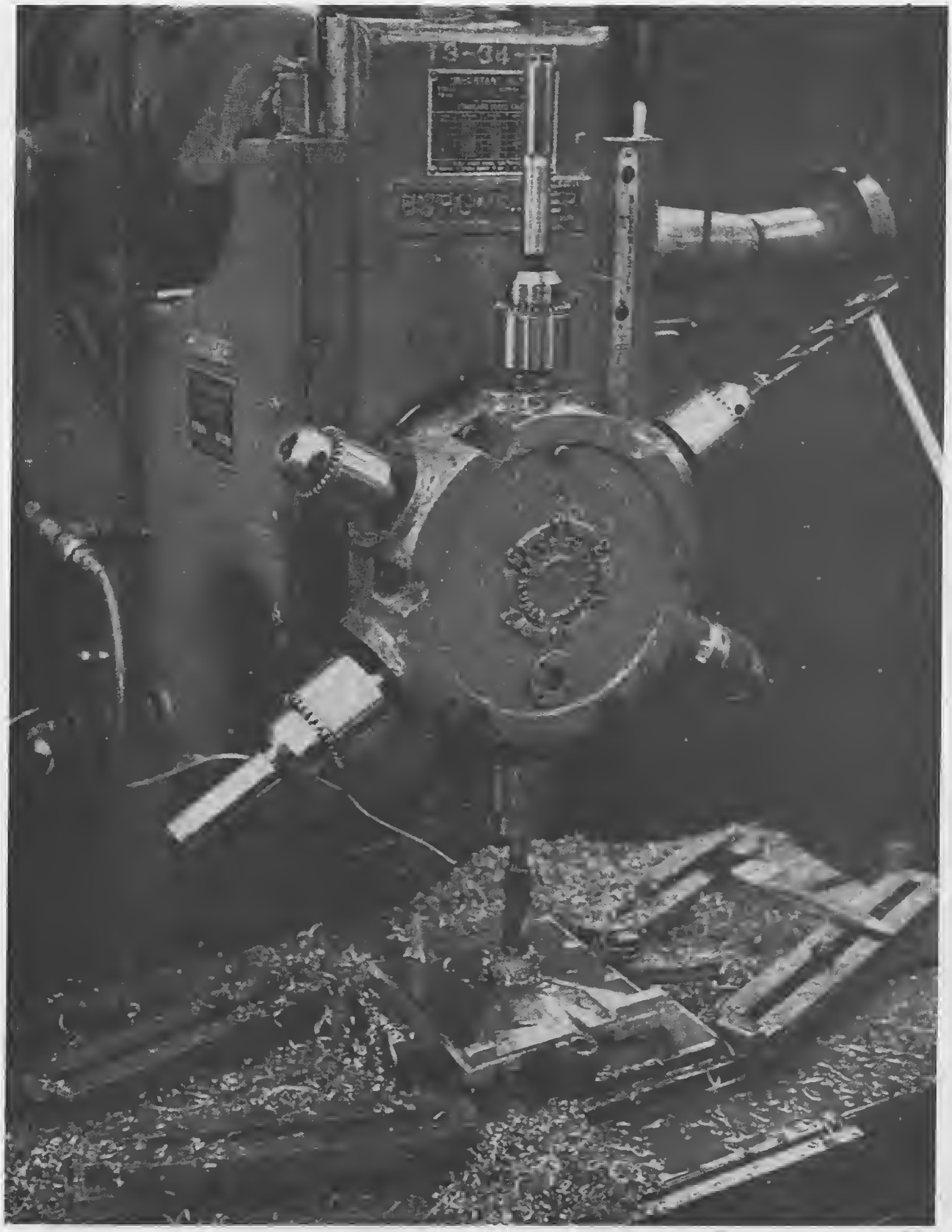

FIGURE 14 - TURRET DRILL (VIEW C)

used in the complete drilling process. The four tools required are: 1) a 31/64" drill, 2) a .501" reamer, 3) a 1/2" drill, and 4) a number 25 drill. The 31/64" drill opens up the two post holes which are next reamed with the .501" reamer. The 1/2" drill is used for the four clearance holes, and the number 25 drill is used for the mounting holes which are to be tapped for a number 8-32 screw.

During drilling, the casting should be held in a drill jig. The main functions of a jig are to position each part from a reference point on the jig, clamp the part firmly during drilling, and guide the drill or reamer into the part.

For three recent production runs using a drill jig, the machine shop time for this part was:

Run	Number of Pieces	Unit Time (hours)[1] (Drilling and Tapping)	(Milling)	Total Unit Time (hours)[1]
1	129	.22	.06	.28
2	166	.16	.07	.23
3	227	.20	.10	.30

Without the use of a jig, tolerances on this part would require drilling by a highly skilled machinist using precision equipment. Production costs per part would be greatly increased. When asked to estimate the time required to drill one of these castings without the use of a jig, an experienced tool and die maker looked at the drawing for about three minutes and said, "All of those tolerances could be held on a vertical milling machine with a Bridgeport head. Such machines in our Model Shop are capable of holding tolerances of $\pm$ .0005. Counting set-up time, drilling, reaming, and tapping, it would take about 1 1/2 hours to put the holes in this casting."

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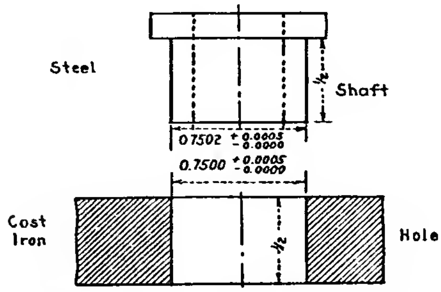
[1] Including the time required to set up machinery, do the machining, and perform quality control.

American Standard Tight Fit, Class 6
Slight Negative Allowance, Selective Assembly
ASA B4a–1925



Jig Bushing. Example of Tight Fit (Class 6)

Summary of Dimensions

	Hole	Shaft	
Tightest Fit	0.7500	0.7507	−0.0007
Loosest Fit	0.7505	0.7502	+0.0003
† Selected Fit	0.7500	0.7502	−0.0002
†† Selected Fit	0.7505	0.7507	−0.0002

Hole stress = 2608 lb./sq. in.

Force for pressing = 1/2 × 0.149 = 0.075 ton.

† Small shaft in small hole.

† Large shaft in large hole.

Formulas

When d = mean size,

Hole Tolerance = $0.0006 \sqrt[3]{d}$

Shaft Tolerance = $0.0006 \sqrt[3]{d}$

Average interference of metal = $0.00025d$.

The average interference of metal is the desired condition and must be obtained by selective assembly that is, by mating large shafts in large holes and small shafts in small holes.

Light pressure is required to assemble these fits and the parts are more or less permanently assembled, such as the fixed ends of studs for gears, pulleys, rocker arms, etc. These fits are used for drive fits in thin sections or extremely long fits in other sections, and also for shrink fits on very light sections. Used in automotive, ordnance, and general machine manufacturing.

Size			Limits				Tightest Fit	Loosest Fit	Selected Fit
From	Up to and Incl.	Mean	Hole or External Member		Shaft or Internal Member		Allowance	Allowance + Tolerances	Average Interference of metal
			+		+	+	−*	*	−*
0	3/16	1/8	0.0003	0.0000	0.0003	0.0000	0.0003	+0.0003	0.0000
3/16	5/16	1/4	0.0004	0.0000	0.0005	0.0001	0.0005	+0.0003	0.0001
5/16	7/16	3/8	0.0004	0.0000	0.0005	0.0001	0.0005	+0.0003	0.0001
7/16	9/16	1/2	0.0005	0.0000	0.0006	0.0001	0.0006	+0.0004	0.0001
9/16	11/16	5/8	0.0005	0.0000	0.0007	0.0002	0.0007	+0.0003	0.0002
11/16	13/16	3/4	0.0005	0.0000	0.0007	0.0002	0.0007	+0.0003	0.0002
13/16	15/16	7/8	0.0006	0.0000	0.0008	0.0002	0.0008	+0.0004	0.0002
15/16	1 1/16	1	0.0006	0.0000	0.0009	0.0003	0.0009	+0.0003	0.0003
1 1/16	1 3/16	1 1/8	0.0006	0.0000	0.0009	0.0003	0.0009	+0.0003	0.0003
1 3/16	1 3/8	1 1/4	0.0006	0.0000	0.0009	0.0003	0.0009	+0.0003	0.0003
1 3/8	1 5/8	1 1/2	0.0007	0.0000	0.0011	0.0004	0.0011	+0.0003	0.0004
1 5/8	1 7/8	1 3/4	0.0007	0.0000	0.0011	0.0004	0.0011	+0.0003	0.0004
1 7/8	2 1/8	2	0.0008	0.0000	0.0013	0.0005	0.0013	+0.0003	0.0005
2 1/8	2 3/8	2 1/4	0.0008	0.0000	0.0014	0.0006	0.0014	+0.0002	0.0006
2 3/8	2 3/4	2 1/2	0.0008	0.0000	0.0014	0.0006	0.0014	+0.0002	0.0006
2 3/4	3 1/4	3	0.0009	0.0000	0.0017	0.0008	0.0017	+0.0001	0.0008
3 1/4	3 3/4	3 1/2	0.0009	0.0000	0.0018	0.0009	0.0018	−0.0000	0.0009
3 3/4	4 1/4	4	0.0010	0.0000	0.0020	0.0010	0.0020	−0.0000	0.0010
4 1/4	4 3/4	4 1/2	0.0010	0.0000	0.0021	0.0011	0.0021	−0.0001	0.0011
4 3/4	5 1/2	5	0.0010	0.0000	0.0023	0.0013	0.0023	−0.0003	0.0013
5 1/2	6 1/2	6	0.0011	0.0000	0.0026	0.0015	0.0026	−0.0004	0.0015
6 1/2	7 1/2	7	0.0011	0.0000	0.0029	0.0018	0.0029	−0.0007	0.0018
7 1/2	8 1/2	8	0.0012	0.0000	0.0032	0.0020	0.0032	−0.0008	0.0020

All dimensions in inches.

* Note: (−) denotes interference of metal or negative allowance.

* Note: (+) denotes clearance or amount of looseness.

EXHIBIT A-1 - PRESS FIT DATA

(Typical for press fits of bushing to plate and liner to plate.)

Interference, Resultant Stresses, and Forces for Tight Fits, Class 6
ASA B4a–1925

Mean Size	Interference of Metal per Inch of Mean Size			Greatest Hole Stress, Steel Shaft in						Force for Pressing Steel Shaft into					
				Steel Hole			Cast-Iron Hole			Steel Hole			Cast-Iron Hole		
	Tightest Fit	Loosest Fit	Selected Fit	Tightest Fit	Loosest Fit	Selected Fit	Tightest Fit	Loosest Fit	Selected Fit	Tightest Fit	Loosest Fit	Selected Fit	Tightest Fit	Loosest Fit	Selected Fit
	Inches	Inches	Inches	Lb per sq. in.	Lb per sq. in.	Lb per sq. in.	Lb per sq. in.	Lb per sq. in.	Lb per sq. in.	Tons	Tons	Tons	Tons	Tons	Tons
1/8	0.00240	No values, due to smallest shaft member in largest hole member	0.00025	69600	No values, due to smallest shaft member in largest hole member	7250	25037	No values, due to smallest shaft member in largest hole member	2608	0.389	No values, due to smallest shaft member in largest hole member	0.000	0.224	No values, due to smallest shaft member in largest hole member	0.000
1/4	0.00200		0.00025	58000		7250	20864		2608	0.649		0.130	0.374		0.075
3/8	0.00133		0.00025	38700		7250	13909		2608	0.649		0.130	0.374		0.075
1/2	0.00120		0.00025	34800		7250	12518		2608	0.779		0.130	0.448		0.075
5/8	0.00112		0.00025	32480		7250	11684		2608	0.909		0.260	0.523		0.149
3/4	0.00093		0.00025	27100		7250	9737		2608	0.909		0.260	0.523		0.149
7/8	0.00091		0.00025	26500		7250	9538		2608	1.038		0.260	0.598		0.149
1	0.00090		0.00025	26100		7250	9389		2608	1.168		0.389	0.672		0.224
1 1/8	0.00080		0.00025	23200		7250	8346		2608	1.168		0.389	0.672		0.224
1 1/4	0.00072		0.00025	20880		7250	7511		2608	1.168		0.389	0.672		0.224
1 1/2	0.00073		0.00025	21300		7250	7650		2608	1.428		0.519	0.822		0.299
1 3/4	0.00063		0.00025	18240		7250	6557		2608	1.428		0.519	0.822		0.299
2	0.00065		0.00025	18850		7250	6781		2608	1.687		0.649	0.971		0.374
2 1/4	0.00062		0.00025	18040		7250	6491		2608	1.817		0.779	1.046		0.448
2 1/2	0.00056		0.00025	16200		7250	5842		2608	1.817		0.779	1.046		0.448
3	0.00057		0.00025	16433		7250	5911		2608	2.207		1.038	1.270		0.598
3 1/2	0.00051		0.00025	14910		7250	5365		2608	2.336		1.168	1.345		0.672
4	0.00050		0.00025	14500		7250	5216		2608	2.596		1.298	1.494		0.747
4 1/2	0.00047	0.00002	0.00025	13530	644	7250	4868	232	2608	2.726	0.130	1.428	1.569	0.075	0.822
5	0.00046	0.00006	0.00025	13340	1740	7250	4799	625	2608	2.985	0.389	1.687	1.719	0.224	0.971
6	0.00043	0.00007	0.00025	12570	1933	7250	4521	695	2608	3.375	0.519	1.947	1.942	0.299	1.121
7	0.00041	0.00010	0.00025	12010	2900	7250	4322	1043	2608	3.764	0.909	2.336	2.167	0.523	1.345
8	0.00040	0.00010	0.00025	11600	2900	7250	4173	1043	2608	4.154	1.038	2.596	2.391	0.598	1.494
				Stress = 29000000 A/d			Stress = 10432000 A/d			Force = 1298 A			Force = 747.2 A		

A = allowance, d = mean size.

Values for stress and force are true only when hub diameter equals twice the hole diameter.

The force values are for fit one inch long. For other lengths multiply by the length of fit in inches.

The values of greatest hole stress are for mean diameter sizes only. For other sizes in a step, the interference per inch of diameter and hence the greatest hole stress will vary from the values given in the table by less than 10 per cent. Where greater accuracy for the intermediate steps is required, the interference per inch of diameter should be obtained by use of the formula: Average interference of metal = 0.00025 d in which d is the diameter of the hole for which the size of the shaft is being computed.

EXHIBIT A-1 (cont.) - PRESS FIT DATA

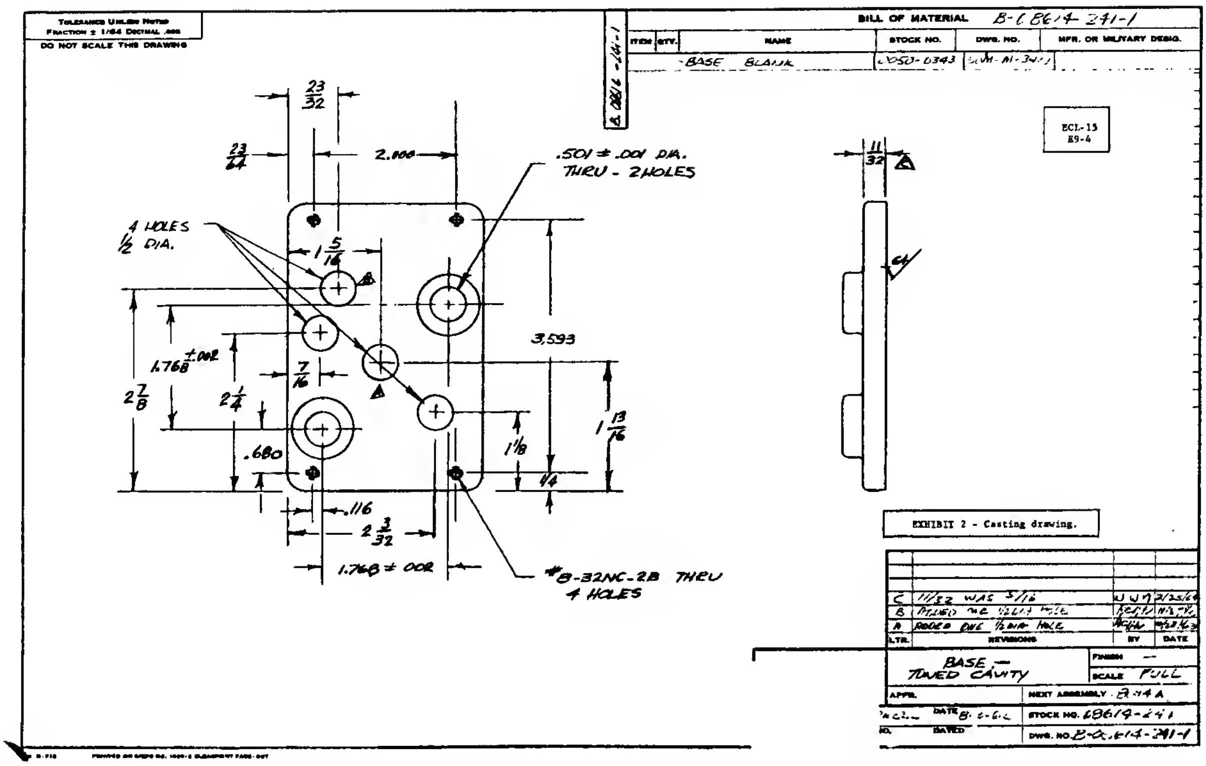


EXHIBIT 2 - Casting drawing.

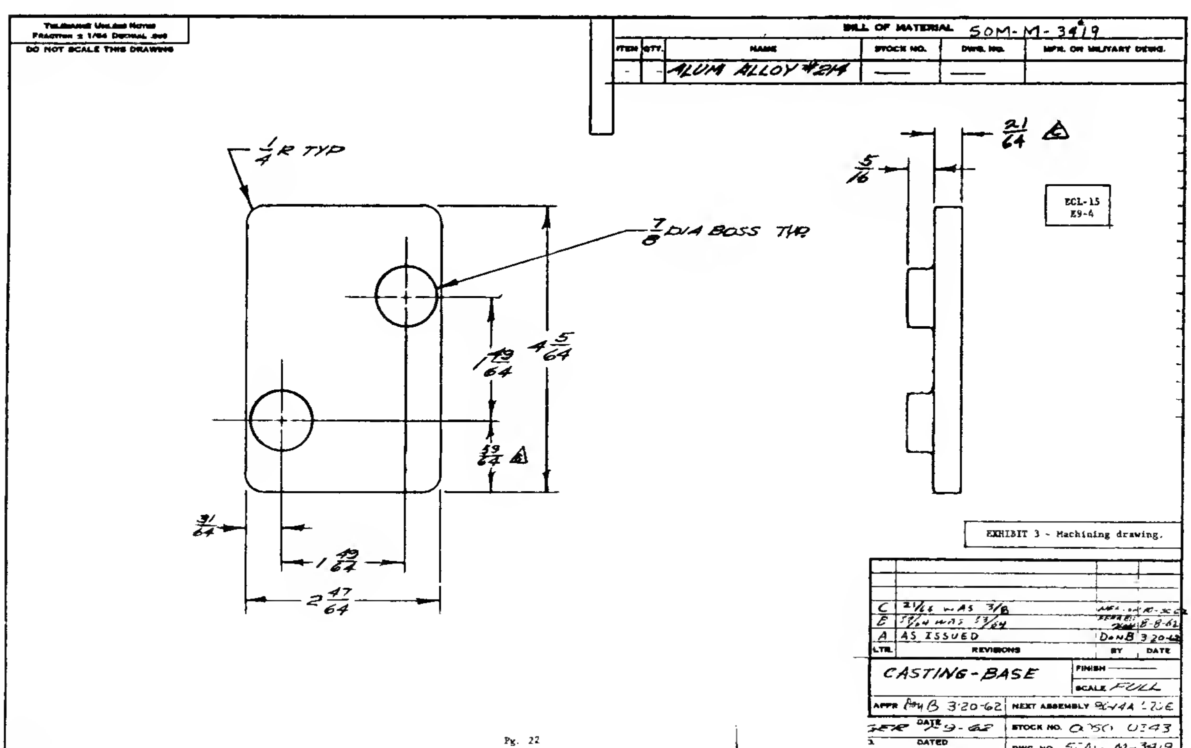


EXHIBIT 3 - Machining drawing.

TECHNICAL DATA

8614A SIGNAL GENERATOR

800 to 2400 mc

Revised 1/24/64

Advantages:

- Digital frequency and attenuator dials
- At least 10 mw output
- Automatic power output control
- AM modulation capability
- Easily carried with one hand
- Only 5¼ inches high
- Rugged and reliable

Use To Measure:

- Receiver sensitivity
- Signal-noise ratio
- Conversion gain
- Standing wave ratios
- Transmission line characteristics
- Antenna characteristics

Operator-oriented Signal Generator

hp Model 8614A Signal Generator is a particularly convenient source for stable, accurate signals from 800 to 2400 mc. Operator error and fatigue are reduced because frequency and attenuation are set on direct reading digital dials. In addition, function (cw, leveled output, square wave modulation, or external amplitude or pulse frequency modulation) is quickly selected by push buttons. Amplitude, frequency, or square wave modulation—with or without leveling—can be accomplished concurrently.

Two power output connectors are furnished which supply rf power simultaneously. One output provides at least 10 mw or a leveled output from 0 dbm to — 127 dbm which is flat within ± ½ db across the band without resetting the attenuator or power monitor. The other provides an uncalibrated output of at least ½ mw.

Operation of Model 8614A is simple because function is push-button selected, frequency and output are read from in-line digital dials, and oscillator-repeller voltage is automatically tracked to frequency.

Pin Modulator

Model 8614A contains a unique PIN diode modulator which allows you to amplitude modulate from dc to 1 mc, or to obtain rf pulses with a 2.0 μsec rise time. Such a broad modulation bandwidth allows remote control of output level or precise leveling using external equipment. The internal leveling, which holds rf output constant within ± 0.5 db, is also obtained by using a PIN modulator.

hp 8614 EEM 2900

HEWLETT-PACKARD COMPANY
1501 PAGE MILL ROAD
PALO ALTO, CALIFORNIA, U.S.A.
CABLE: "HEWPACK" TEL. (415) 326-7000
54 ROUTE DES ACACIAS
GENEVA, SWITZERLAND
CABLE: "HEWPACKSA" TEL. (022) 42.81.50

PRINTED IN U.S.A.

1-Watt Output/High Speed Modulation-- With Accessories

When up to one watt output is required above 1000 mc the hp 489A (1 gc to 2 gc) or hp 491C (2 gc to 4 gc) Microwave Amplifiers serve as ideal power boosters. The hp 8714 high speed modulator is also available for use with the 8614A Signal Generator when a sophisticated high-speed, low-jitter modulation system is needed. The 8714A Modulator also offers a wide selection of pulse and square wave modulation.

General

Because of its wide range and great stability, the hp 8614A Signal Generator is ideal for the most precise UHF applications. Its compact design and light weight are such that the instrument may be carried with one hand. It not only saves bench space, but the 5¼-in. panel height is a real space saver to those interested in rack mounting. Ruggedly built of the finest components, the hp 8614A is designed for many years of trouble-free service and in-specification accuracy.

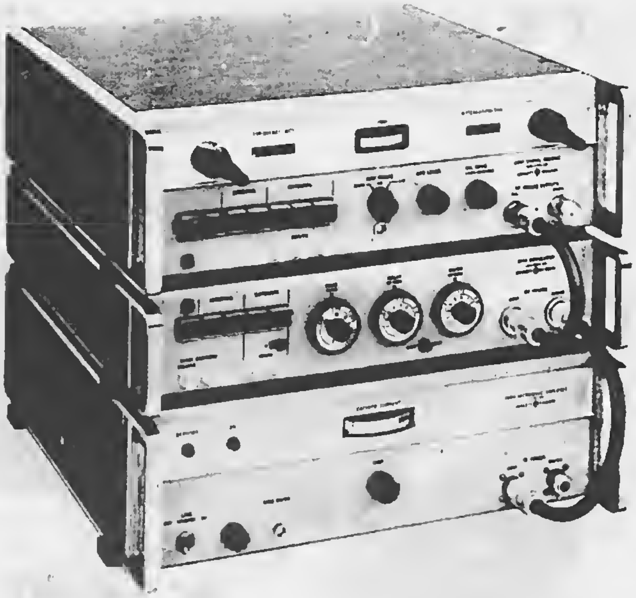


Figure 1. hp Models 8614A, 8714A, and 489A form a sophisticated 1-watt source for frequencies from 1 to 2 gc.

Specifications

Output

Frequency Range: 800 to 2400 mc; single, linearly calibrated control; direct reading within 2 mc.

Vernier: Δ F control has range of 2 mc for fine tuning.

Frequency Calibration Accuracy: ± 5 mc.

► **Frequency Stability:** Approximately 0.005%/°C change in ambient temperature, less than 2500 cps peak residual fm, negligible incidental fm in pulse and AM operation for attenuator settings below — 10 db, less than 0.003% change with line voltage variation of ± 10%.

RF Output Power: + 10 dbm (10 mw) to — 127 dbm (0.1 μvolt) into a 50-ohm load. Output attenuator dial directly calibrated in dbm from 0 to — 127 dbm. A second uncalibrated rf output (approximately 0.5 mw minimum) is provided on the front panel.

RF Output Power Accuracy *(with respect to attenuator dial):* ± 0.75 db + attenuator accuracy (— 10 to — 127 dbm); + 0, — 3 db (0 to — 10 dbm); uncalibrated above 0 dbm. (Includes leveled output variations.)

Attenuator Accuracy: ± 0.06 db/10 db from — 10 db to — 127 db; direct reading linear dial, 0.2 db increments.

Leveled Output: Constant within ± 0.5 db across entire frequency range at any attenuator setting below 0 db. Output power can be adjusted from — 4 to + 4 dbm of the normal calibrated level with the Automatic Level Control.

Internal Impedance: 50 ohms, swr less than 2.0.

Modulation

Internal Square Wave: 800 to 1200 cps. Other frequencies available on special order. On-off ratio at least 20 db.

► **External Pulse:** 50 cps to 50 kc, 2.0 μsec rise time. + 20 to + 100 v peak input. On-off ratio at least 20 db.

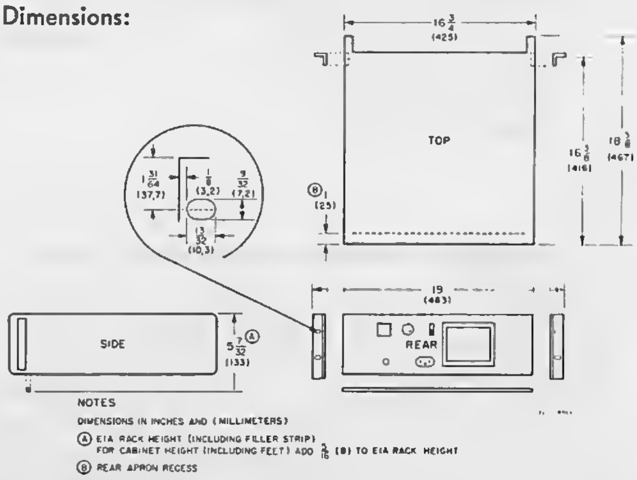
External AM: DC to 1 mc.

External FM: Mode width between 3 db points varies from a minimum of approximately 4 mc at a frequency of 800 mc to a maximum of approximately 15 mc at a frequency of 2000 mc. Sensitivity is approximately 100 kc/volt between 800 and 1600 mc and 200 kc/volt between 1600 and 2400 mc.
(a) Front-panel connector capacitively coupled to the repeller of the klystron.
(b) Rear-panel connector is dc-coupled to the repeller of the klystron.

General

Power Source: 115 or 230 volts ± 10%, 50 to 60 cps, approximately 125 watts.

Dimensions:



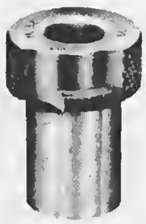
Weight: Net, 48 lbs. *(22 kg)*. Shipping, approximately 63 lbs. *(28 kg)*.

► **Price:** hp Model 8614A, $2,100.00.

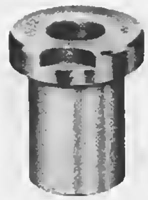
► **Option 01.** External modulation input connectors on rear panel in parallel with front-panel connectors; rf connectors on rear panel only. Add $25.00.

Prices f.o.b. factory
Data subject to change without notice
► Indicates change from prior specifications

10/28/63
1/24/64

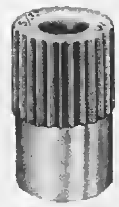


SLIP RENEWABLE BUSHINGS
A.S.A. Standard and Thin Wall

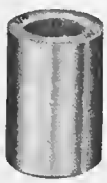


FIXED RENEWABLE
A.S.A. Standard and Thin Wall

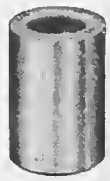
HEAD PRESS FIT
A.S.A. Standard and Thin Wall



HALF-SERRATED

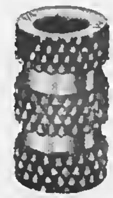


PRESS FIT
A.S.A. Standard and Thin Wall



LINER
A.S.A. Standard and Thin Wall

HEAD LINER
A.S.A. Standard



GROOVED DIAMOND KNURLED

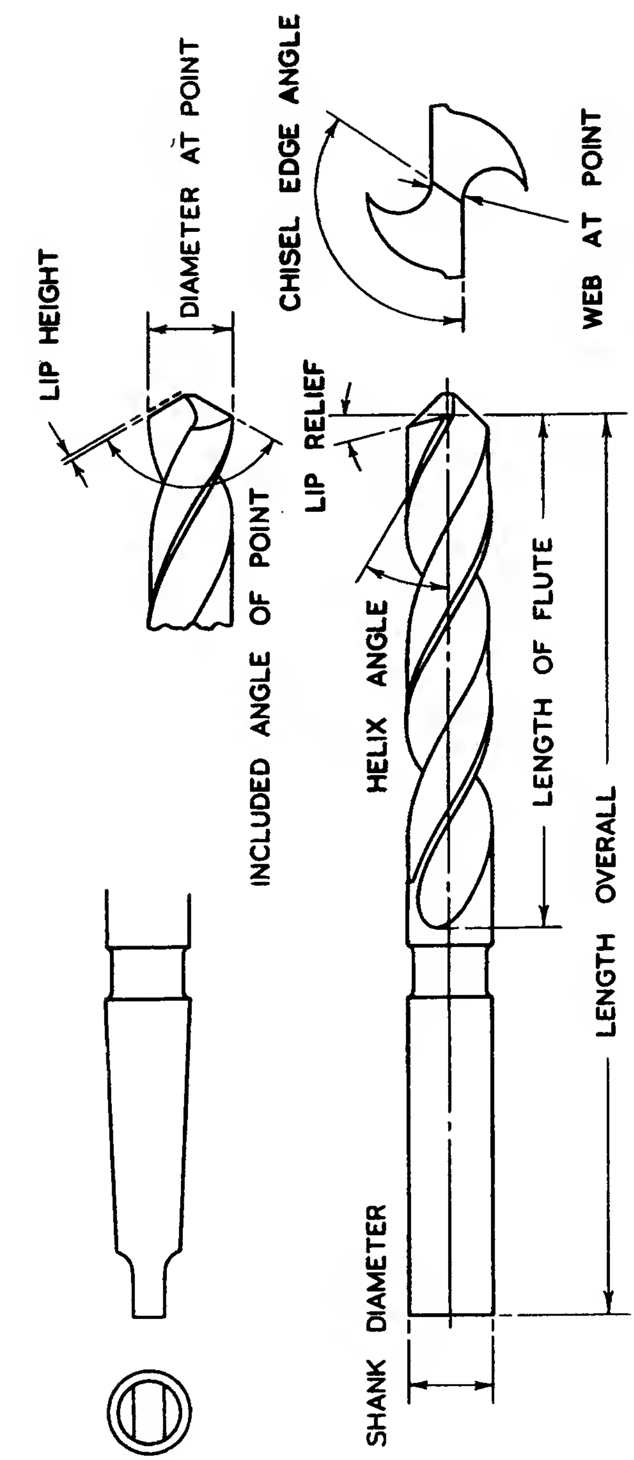
	STANDARD DRILL SIZES	I.D.	I.D. TOLERANCE	O.D. TOLERANCE
DRILL BUSHING AND LINER TOLERANCES	#80 — 1/4	NOM.	+.0001 to +.0004	+.0001 to +.0005
	1/4 — 3/4	NOM.	+.0001 to +.0005	+.0001 to +.0006
	3/4 — 1 1/2	NOM.	+.0002 to +.0006	+.0002 to +.0007
	1 1/2 — 2 3/4	NOM.	+.0003 to +.0007	+.0003 to +.0008

	STANDARD REAMER SIZES	I.D.	I.D. TOLERANCE	O.D. TOLERANCE
REAMER BUSHING TOLERANCES	UP TO 1/4	NOM.	+.0005 to +.0008	+.0001 to +.0006
	1/4 — 1	NOM.	+.0006 to +.0010	+.0002 to +.0007
	OVER 1	NOM.	+.0008 to +.0012	+.0003 to +.0008

I.D. AND O.D. CONCENTRIC WITHIN .0004"
TOTAL INDICATOR READING

EXHIBIT 5 - Bushing types and tolerances.

SECTION I—TWIST DRILLS, TWO FLUTE, GENERAL PURPOSE



Identity of Toleranced Areas

EXHIBIT 6 - TWIST DRILL TOLERANCES

SECTION I—TWIST DRILLS, TWO FLUTE, GENERAL PURPOSE

Tolerance tables 1 thru 10 apply to general purpose, high speed steel twist drills of the following types:

Taper Shank Drills
Straight Shank Taper Length Drills
Straight Shank Jobbers Length Drills

Table 1—Diameter at Point

Drill Diameter Range		Tolerance
No. 80 to 3/64″	(.0135 to .0469) Incl.	+.0000 to −.0006
No. 55 to 1/8″	(.0520 to .1250) Incl.	+.0000 to −.0008
No. 30 to 1/4″	(.1285 to .2500) Incl.	+.0000 to −.0010
F to 3/4″	(.2570 to .7500) Incl.	+.0000 to −.0015
49/64 to 1 1/2″	(.7656 to 1.5000) Incl.	+.0000 to −.0020
1 33/64 to 3 1/2″	(1.5156 to 3.5000) Incl.	+.0000 to −.0025

Table 2—Shank Diameters* (SS Drills)

Drill Diameter Range		Tolerance
up to 5/32″	(Up to .1562) Incl.	+.0000 to −.0025
No. 22 to 1/4″	(.1570 to .2500) Incl.	−.0005 to −.0035
F to 3/8″	(.2570 to .3750) Incl.	−.0010 to −.0040
25/64 to 1/2″	(.3906 to .5000) Incl.	−.0015 to −.0045
33/64 to 2″	(.5156 to 2.0000) Incl.	−.0005 to −.0030

*As Measured at Shank End

Table 3—Back Taper

Drill Diameter Range		Tolerance
No. 80 to 5/32″	(.0135 to .1562) Incl.	.0000 to .0008 Per Inch
No. 22 to 21/64″	(.1570 to .3281) Incl.	.0002 to .0008 Per Inch
Q to 1/2″	(.3160 to .5000) Incl.	.0002 to .0009 Per Inch
33/64 to 3/4″	(.5156 to .7500) Incl.	.0002 to .0011 Per Inch
49/64 to 31/32″	(.7656 to .9688) Incl.	.0002 to .0012 Per Inch
63/64 to 1 1/2″	(.9844 to 1.5000) Incl.	.0002 to .0015 Per Inch
1 33/64 to 3 1/2″	(1.5156 to 3.5000) Incl.	.0002 to .0020 Per Inch

Table 4—Length of Flute

Drill Diameter Range		Tolerance
No. 80 to 1/8″	(.0135 to .1250) Incl.	+1/8 to −1/16
No. 30 to 1/2″	(.1285 to .5000) Incl.	+1/8 to −1/8
33/64 to 1″	(.5156 to 1.0000) Incl.	+1/4 to −1/8
1 1/64 to 2″	(1.0156 to 2.0000) Incl.	+1/4 to −1/4
2 1/32 to 3 1/2″	(2.0313 to 3.5000) Incl.	+3/8 to −3/8

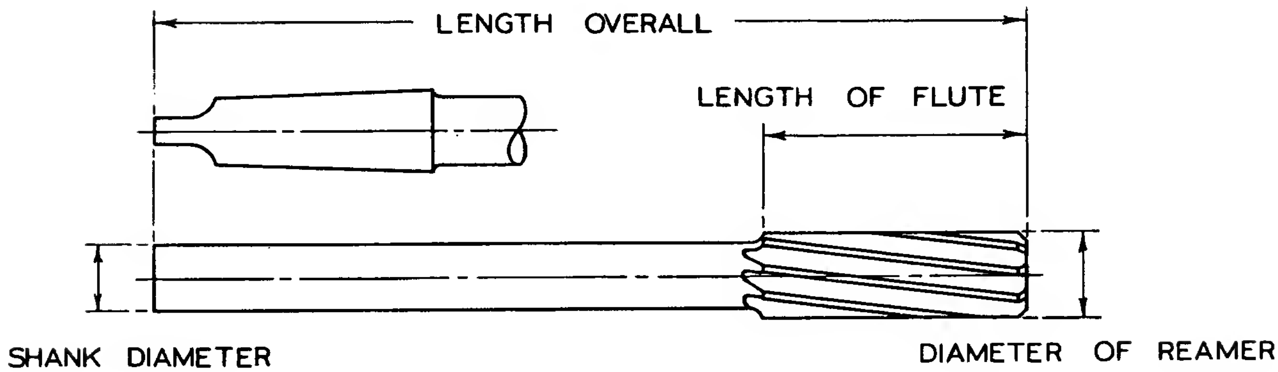
Table 5—Length Overall

Drill Diameter Range		Tolerance
No. 80 to 1/8″	(.0135 to .1250) Incl.	+1/8 to −1/16
No. 30 to 1/2″	(.1285 to .5000) Incl.	+1/8 to −1/8
33/64 to 1″	(.5156 to 1.0000) Incl.	+1/4 to −1/8
1 1/64 to 2″	(1.0156 to 2.0000) Incl.	+1/4 to −1/4
2 1/32 to 3 1/2″	(2.0313 to 3.5000) Incl.	+3/8 to −3/8

EXHIBIT 6 (cont.) TWIST DRILL TOLERANCES

SECTION III—REAMERS

Tolerance tables 12 thru 15D apply to high speed and carbon steel reamers as identified under each separate table, and further identified in the American Standard "ASA B5.14—1959 Reamers".



Identity of Toleranced Areas

Table 12—Diameter of Reamer

Reamer Diameter Range		Tolerance
No. 60 to ¼″	(.0400 to .2500) Incl.	+.0001 to +.0004
F to 1″	(.2570 to 1.0000) Incl.	+.0001 to +.0005
1¹⁄₁₆ to 3″	(1.0625 to 3.0000) Incl.	+.0002 to +.0006

Applies to:
1—Hand Reamers with straight or helical flutes & squared shanks
2—Taper shank jobbers reamers with straight flutes
3—Shell reamers with straight or helical flutes
4—Expansion chucking reamers, straight flute, straight or taper shank
5—Chucking reamers, straight or helical flute, straight or taper shank
6—Stub Screw Machine Reamers

Table 13—Length of Flute

Reamer Diameter Range		Tolerance
No. 60 to 1″	(.0400 to 1.0000) Incl.	+¹⁄₁₆ to −¹⁄₁₆″
1¹⁄₁₆ to 2″	(1.0625 to 2.0000) Incl.	+³⁄₃₂ to −³⁄₃₂″
2¹⁄₁₆ to 3″	(2.0625 to 3.0000) Incl.	+⅛ to −⅛″

Applies to:
1—Hand Reamers with straight or helical flutes & squared shanks
2—Taper shank jobbers reamers with straight flutes
3—Shell reamers with straight or helical flutes
4—Expansion chucking reamers, straight flute, straight or taper shank
5—Chucking reamers, straight or helical flute, straight or taper shank
6—Stub Screw Machine Reamers
7—Expansion hand reamers, straight flute and squared shank

EXHIBIT 7 - REAMER TOLERANCES

HEWLETT-PACKARD COMPANY III (B)

Drill Jig Tolerances

After designing the drill jig and making layout and detail drawings, the tool engineer had to choose dimensions and tolerances for the drill jig assembly. The components of the jig had to fit together and guarantee that the tolerances on the end plate were met.

Drill Jig Design

In designing the end plate, the designer did not feel it necessary to consult with a tool engineer about the drilling operations. He felt that the drilling operations required on this part would not cause any unusual problems in drill jig design for tool engineers. Consequently, the first contact the tool engineering department had with this part was a written order to design tooling needed for its production.

Upon receipt of the production drawing of the part, the tool engineer in the casting shop checked with the production control department to determine the quantity of parts in the production forecast. This called for 600 instruments per year. He explained the importance of this step. "This gives the engineer the clue to the type of machinery which will be used to produce the part. If the part to be drilled is a low quantity item (this would be around 500 or less pieces per year for a simple part), it will be drilled on a single spindle drill press. For medium quantity simple items (between 500 and 1000 pieces per year) the drilling would be done on a six spindle turret drill such as we are using on this cast end plate (Figures 15 and 16). For high quantity items, we use a multi-spindle drill (Figures 17 and 18) which can drill several holes simultaneously."

"Once I know the type of machinery to be used, I can decide upon the type of clamping which will be necessary to hold the part in the jig during drilling. The more drills you have going into the part at the same time, the stronger the clamping force required. From here on in the jig design, I try to use inexpensive standard purchased items as much as possible."

Prepared in the Design Division, Department of Mechanical Engineering, Stanford University by Eugene Echterling, under the direction of Professor Peter Z. Bulkeley with National Science Foundation support. The cooperation of Carl Buchass and Ronald Gross of the Hewlett-Packard Company is gratefully acknowledged.

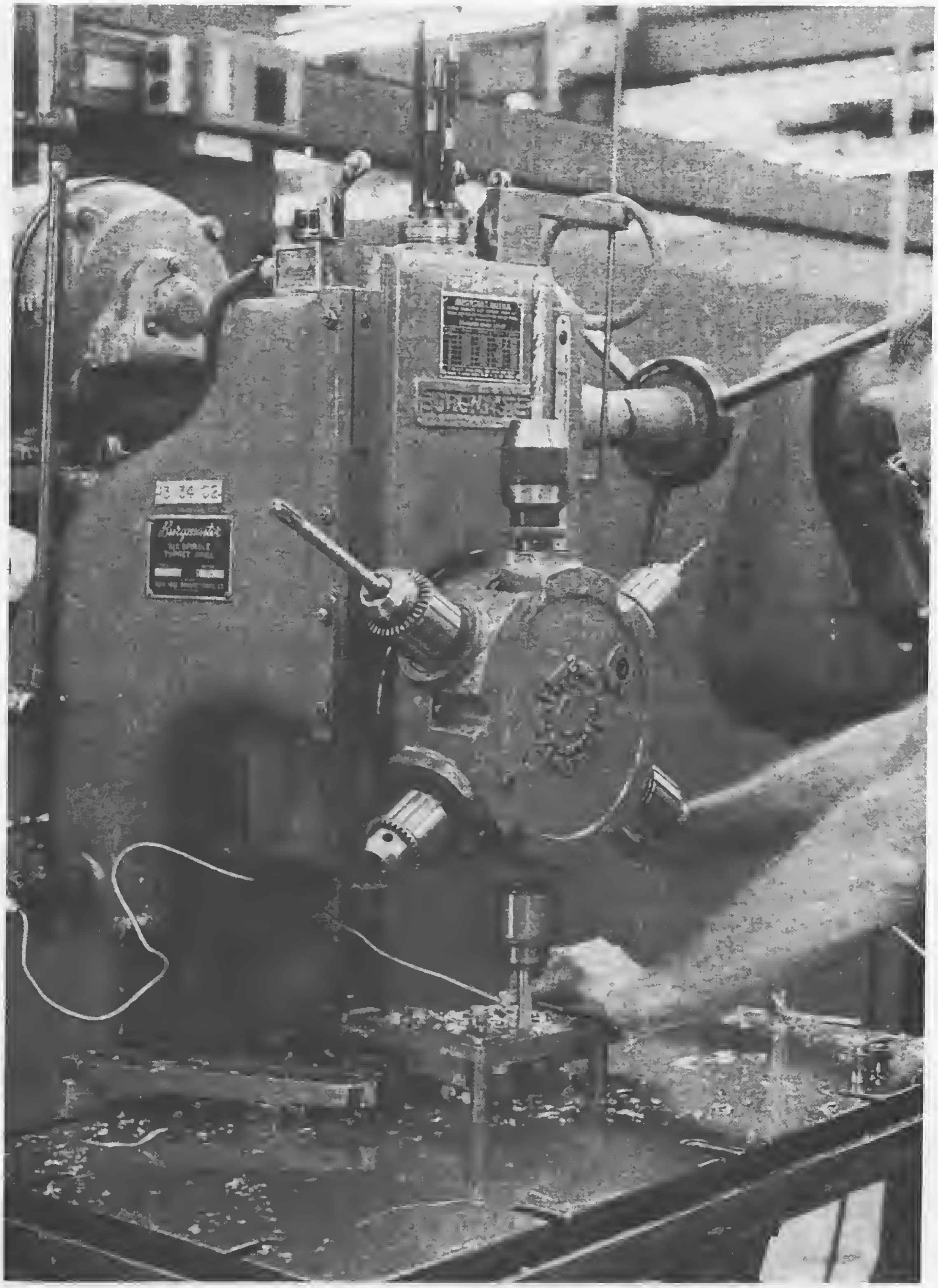


FIGURE 15 - DRILLING THE CASTING WITH THE AID OF A DRILL JIG

FIGURE 16 - CHANGING BUSHINGS BEFORE REAMING
THE BOSSES OF THE CASTING

FIGURE 17 - MULTI-DRILLING HEAD MOUNTED ON A SINGLE SPINDLE DRILL PRESS

FIGURE 18 - MULTI-DRILLING HEAD WITH AN
ATTACHED DRILL JIG

The drill jig (Figures 19-21) used for the end plate is the type commonly referred to as a "box jig" due to its resemblance to a rectangular box. The basic parts of the jig are a drilling plate, locating dowels, clamps, legs, and bushings.

The drilling plate is the basic structure to which the other components are attached. The hardened steel drill bushings, which guide the drills into the part, are fitted into the plate. Several different types of bushings are used in this jig. All except two are press fit permanently in the plate. Bushings for drilling the four clearance holes and the four mounting holes are press fit. The bushings for the two holes in the bosses, however, are removable. This is necessary because there are two operations performed on these holes. For use of a removable drill bushing, a hardened steel liner is first fitted into a hole in the drilling plate. The outside diameter of the liner produces a press fit in the plate. The inside diameter of the liner is ground to a snug fit on the outside diameter of the slip bushing, which can readily be inserted into the liner and removed with the fingers. The function of the liner is to provide a hard, smooth, accurate fit for the bushing. A liner must be used to maintain the proper fit for slip renewable bushings. Without it, the hole in the plate would soon wear from frequent insertion and removal of the bushing, causing inaccurate alignment. Adjacent to the liner is a tapped hole in the drill plate. This is for a lock screw which holds the bushing in the plate and prevents turning of the bushing. The head of the slip bushing is slotted horizontally and vertically, allowing it to slip past the head of the locking screw and to twist for locking to the plate. The knurled head of the slip bushing allows it to be easily handled with the fingers.

Clamping the part in the jig is accomplished by five thumb screws which secure it against the locating buttons.

Legs are provided to position the jig horizontally on the drill bed. Resting on legs instead of flat sides reduces the chance of improper alignment due to chips of metal under the jig (Illustration A).

Illustration A

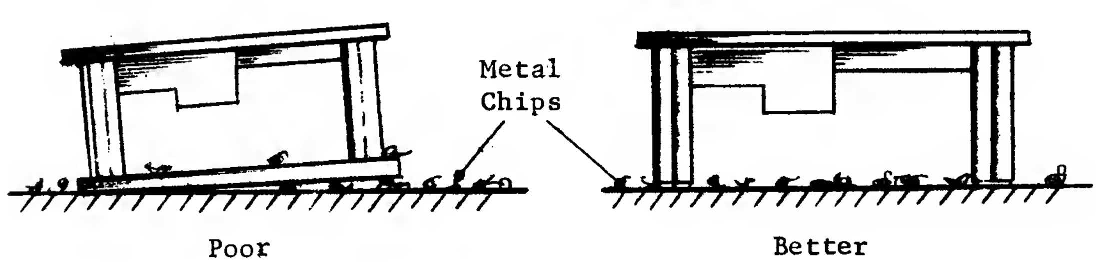


FIGURE 19 - DRILL JIG AND SAMPLE PART SHOWN IN NORMAL LOADING POSITION

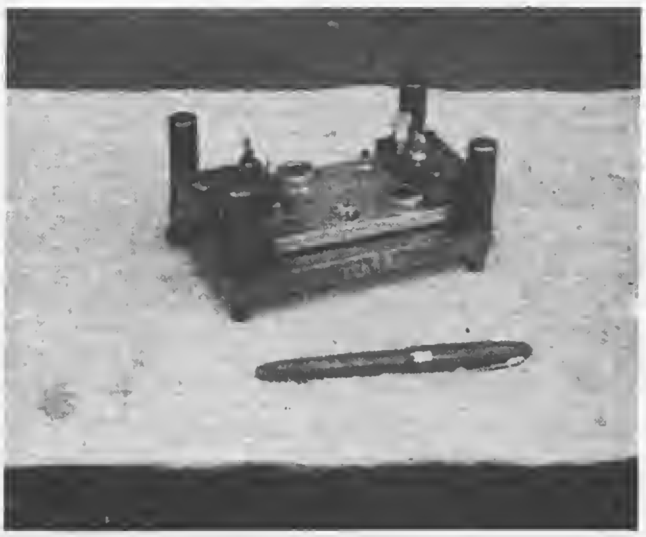


FIGURE 20 - LOADED DRILL JIG IN THE POSITION FOR DRILLING THE FOUR MOUNTING HOLES

FIGURE 21 - LOADED DRILL JIG IN POSITION FOR DRILLING THE CLEARANCE AND GUIDE-POST HOLES

The casting is inserted from the side as the jig sits with its four legs pointing upward. Four rest buttons support the part about 1/8" above the surface of the plate.

Location in the jig is accomplished by inserting the part until it stops against two dowel pins. A thumb screw in one clamp is then turned, clamping the part against the inside surface of the other clamp. Four thumb screws in the overhanging portions of the clamps are then tightened, holding the part on the four rest buttons. The overhang of the clamps is such that the two raised bosses on the part clear the overhang by about 1/8". This prevents improper insertion of the part. Thus, there is only one position the part can assume in the jig. This is a very important aspect of jig design. If a jig is designed with more than one possible position for the part in the jig, the machine operator is required to check after each insertion to see that the part is properly positioned. This takes additional time, and, if not done carefully, can result in improperly drilled parts which must be scrapped.

After all five thumb screws have been tightened against the part, it is ready for drilling.

For the first drilling operation, the jig has its four long legs pointing upward. It rests on the tapped ends of the legs which protrude through the plate and act as legs in this position. In each overhanging clamp edge, there are two number 25 drill bushings for the mounting holes. After these are drilled, the jig is inverted, exposing the bushings in its face plate.

Drilling of the four clearance holes to 1/2" diameter is next, followed by rough drilling of the bosses to 31/64" diameter.

The removable drill bushings for the bosses are then replaced by .501" diameter reamer bushings. A .501" diameter reamer is then passed through each of the bosses, completing the drilling operation.

The final machining operation involves tapping the four mounting holes for a number 8-32 screw. For this operation, the part is removed from the drill jig and placed on a simple block of wood. No clamping is required for the tapping operation.

Three assembly views of the drill jig are shown as Exhibits B-1, B-2, and B-3. From Exhibit B-5 we see that no critical dimensions are included on the detailed drawings of the jig components. All dimensions are fractional with the relatively loose tolerance of $\pm$ 1/64. The critical location of holes and reference surfaces if done when all parts of the jig are finally assembled. These dimensions, therefore, must appear on the assembly drawing.

To stay within the tolerance of $\pm$ .002 inches on the dimensions locating the holes in the bosses of the plate, the tolerance buildup of all parts related to these holes must be considered. Thus, we must consider tolerances on drill size, bushing inner diameter, bushing outer diameter, liner diameter, and the bushing hole location in the plate.

Exhibit B-2 shows a top view layout of the assembled jig prior to the tool engineer's placement of hole location dimensions and tolerances. It is on this view that the critical positional dimensions should be placed. In selecting tolerances, a balance must be made between the loosest tolerances possible (to minimize cost of building the jig) and the closest tolerances desired (to assure proper hole locations in the casting).

The finished drawing will be given to a tool and die maker who will produce the jig. It is the responsibility of the tool engineer to see that all necessary purchased items are on hand when the tool maker is ready for them. When assembling the jig, the tool maker usually locates finished components correctly by firmly clamping mating parts together for simultaneous drilling and reaming of dowel holes in the mating parts. This eliminates the problem of misfit which can occur when mating parts are reamed individually for press-fit doweled assembly.

When mounting press-fit bushings or liners in the jig plate, the tool maker first drills a hole approximately .005" undersize in the plate. This hole is then further opened up to its final size with a reamer. For press-fit bushings and liners, the fit described in Exhibit A-1 is normally used. This fit allows the bushing to be pressed out of the plate and replaced if the bushing begins to show wear after prolonged use.

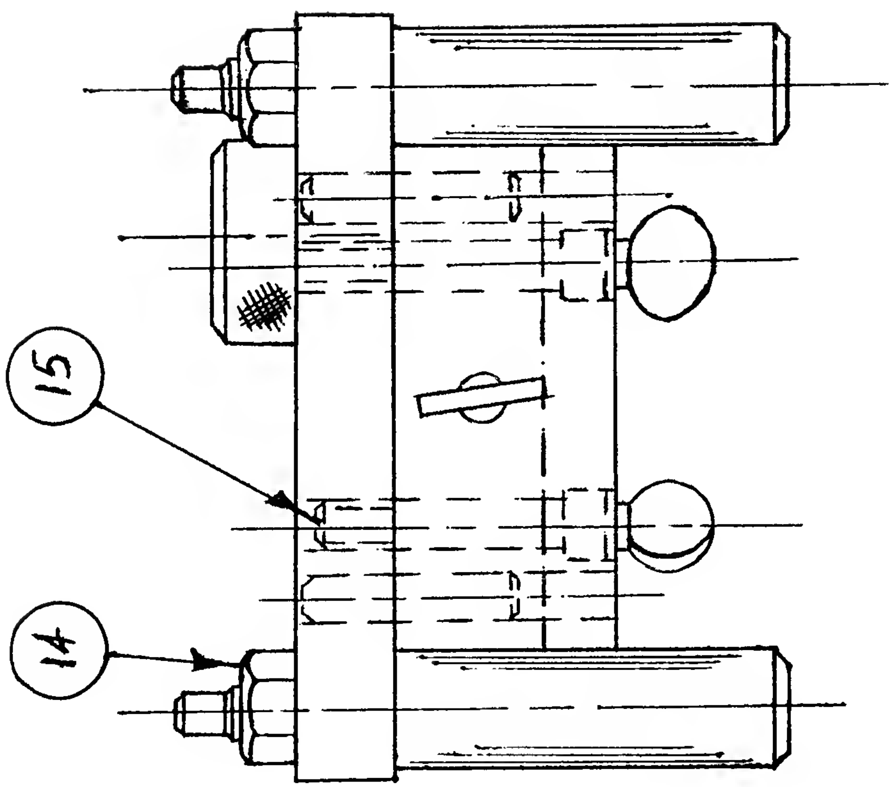


Exhibit B-1 - Drill jig layout drawing (End view).

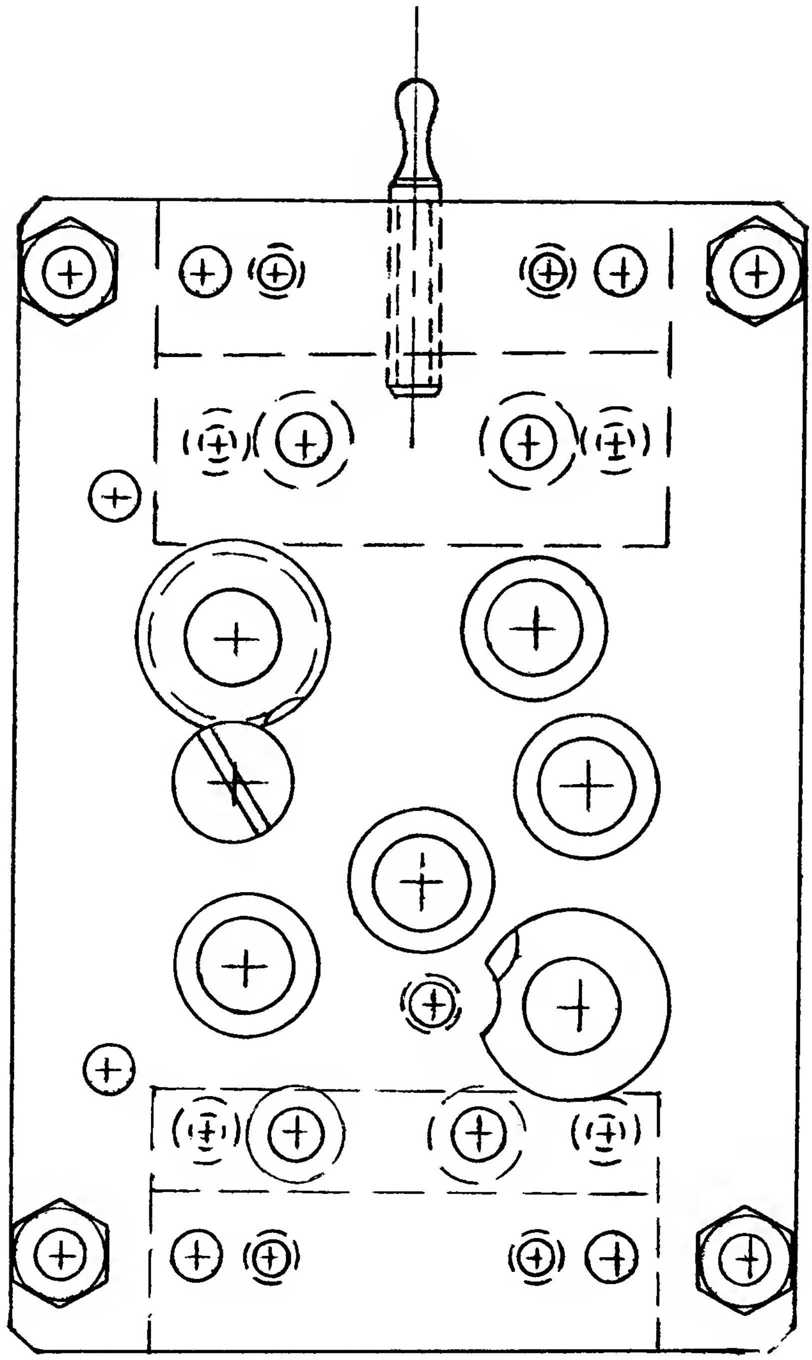
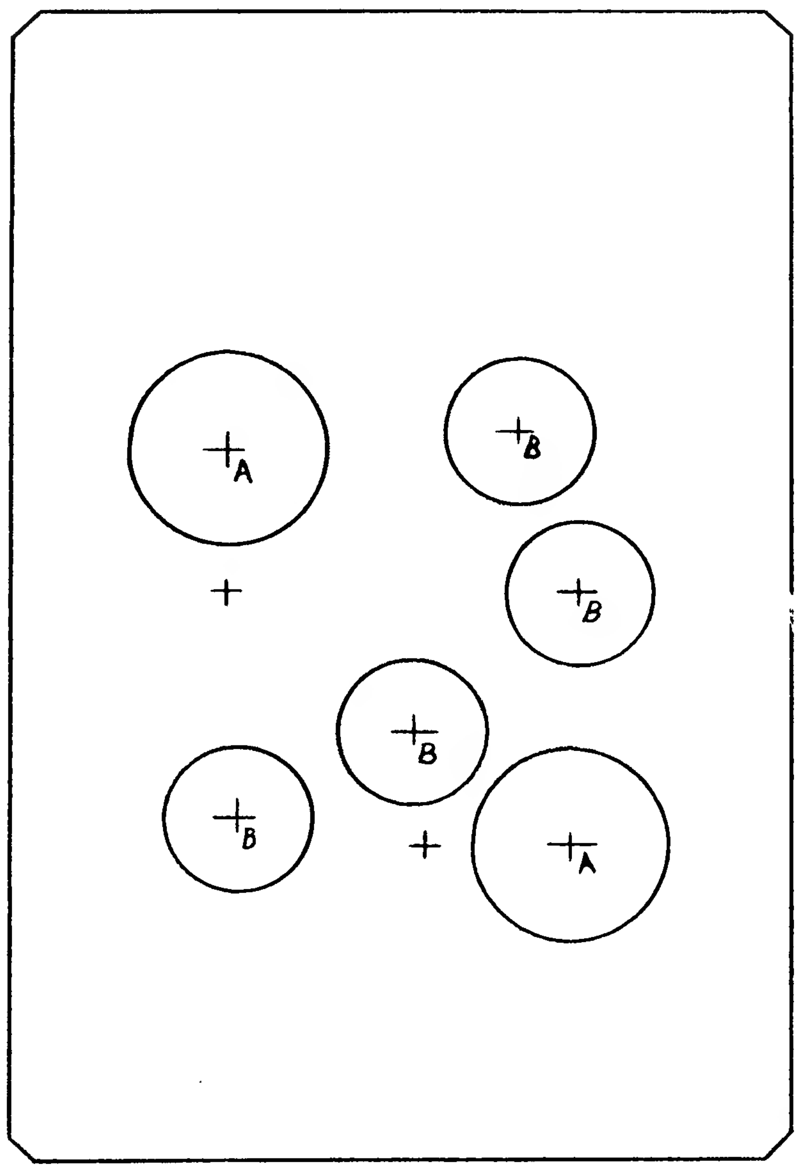


Exhibit B-2 - Drill jig layout drawing (Top view).

Exhibit B-2a: Detail 7 , Drill Jig Plate (bushing holes only).



A = 1" DIA. FOR DET. 10

B = .750" DIA. FOR DET. 4

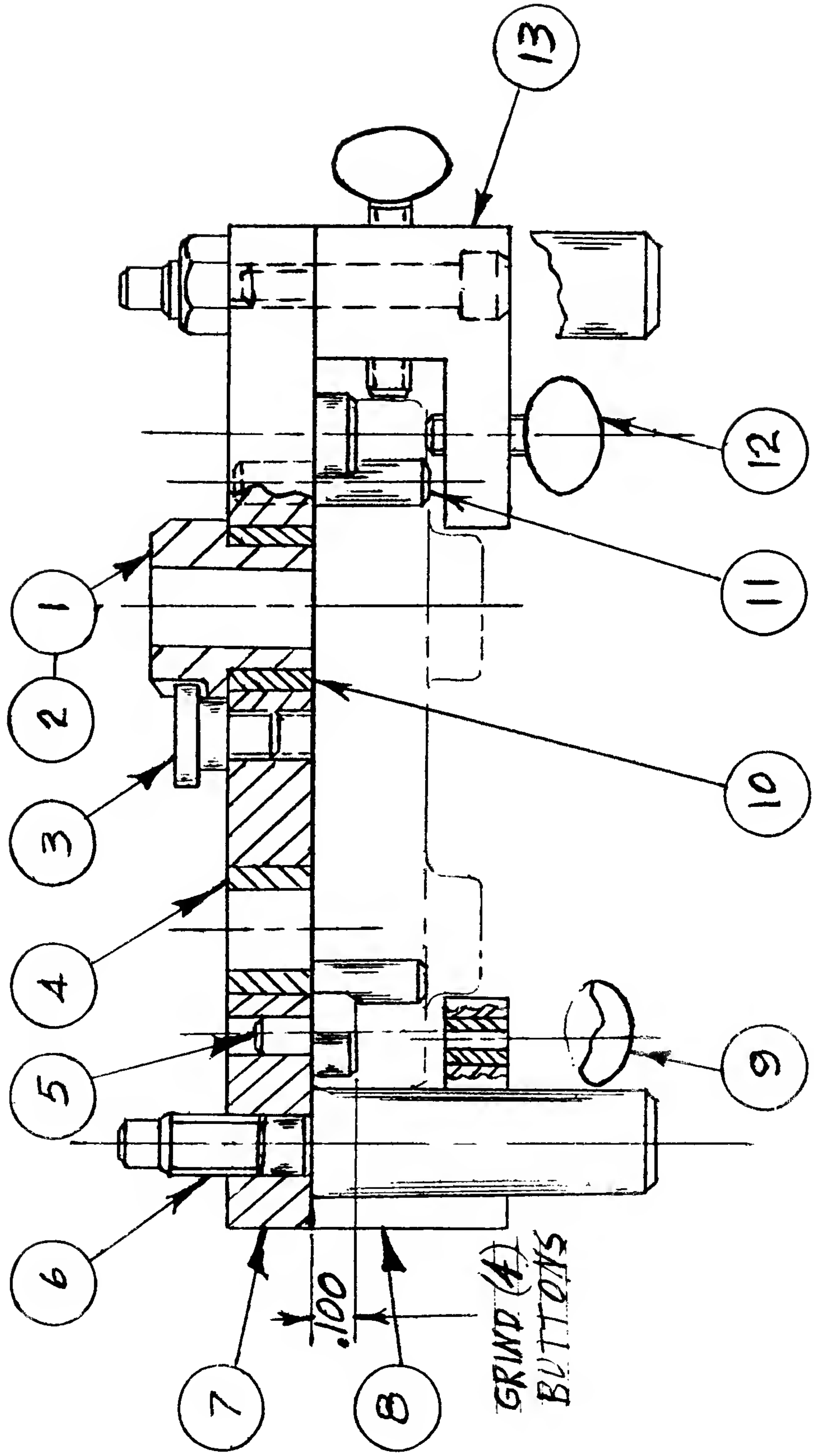


Exhibit B-3 - Drill Jig Layout Drawing (Side View)

		BILL OF MATERIAL		
ITEM	QTY.	NAME	SOURCE	REMARKS
1	1	31/64 I.D. DRL. BUSH.	AMERICAN	TYPE 'SR' 3/4 O.D. x 1/2 LG.
2	1	501 I.D. REAMER BUSH.	AMERICAN	TYPE 'SR' 3/4 O.D. x 1/2 LG.
3	2	LOCK SCR. NO. 3	ACE	3/8 - 16
4	4	1/2 I.D. DRL. BUSH.	AMERICAN	TYPE 'P' 3/4 O.D. x 1/2 LG.
5	4	REST BUTTONS	STD.PTS.CO.	RB-250-25
6	4	JIG LEG	STD.PTS.CO.	JL-625-2
7	1	DRL. PLATE	C.R.S.	1/2 x 4" x 6 1/8 LG.
8	1	LOCATOR CLAMP	C.R.S.	1 1/4x6"x1 7/8 LG.(MAKES NO.13 ALSO)
9	4	NO. 25 I.D DRL. BUSH.	AMERICAN	TYPE 'P' 5/16 O.D. x 3/8 LG.
10	2	3/4 I.D. LINER BUSH.	AMERICAN	1" O.D. x 1/2 LG.
11	6	1/4 DOWEL	STD.	x 1 1/8 LG.
12	5	1/4 - 20 WING BOLT	STD.	SEE NOTE
13	1	CLAMP	C.R.S.	SEE DET. 8 MAT'LS.
14	4	5/16 - 24 HEX NUT	STD.	
15	4	1/4 - 20 S.H.C. SCR.	STD.	x 1 3/8

Exhibit B-4 - Drill jig parts list.

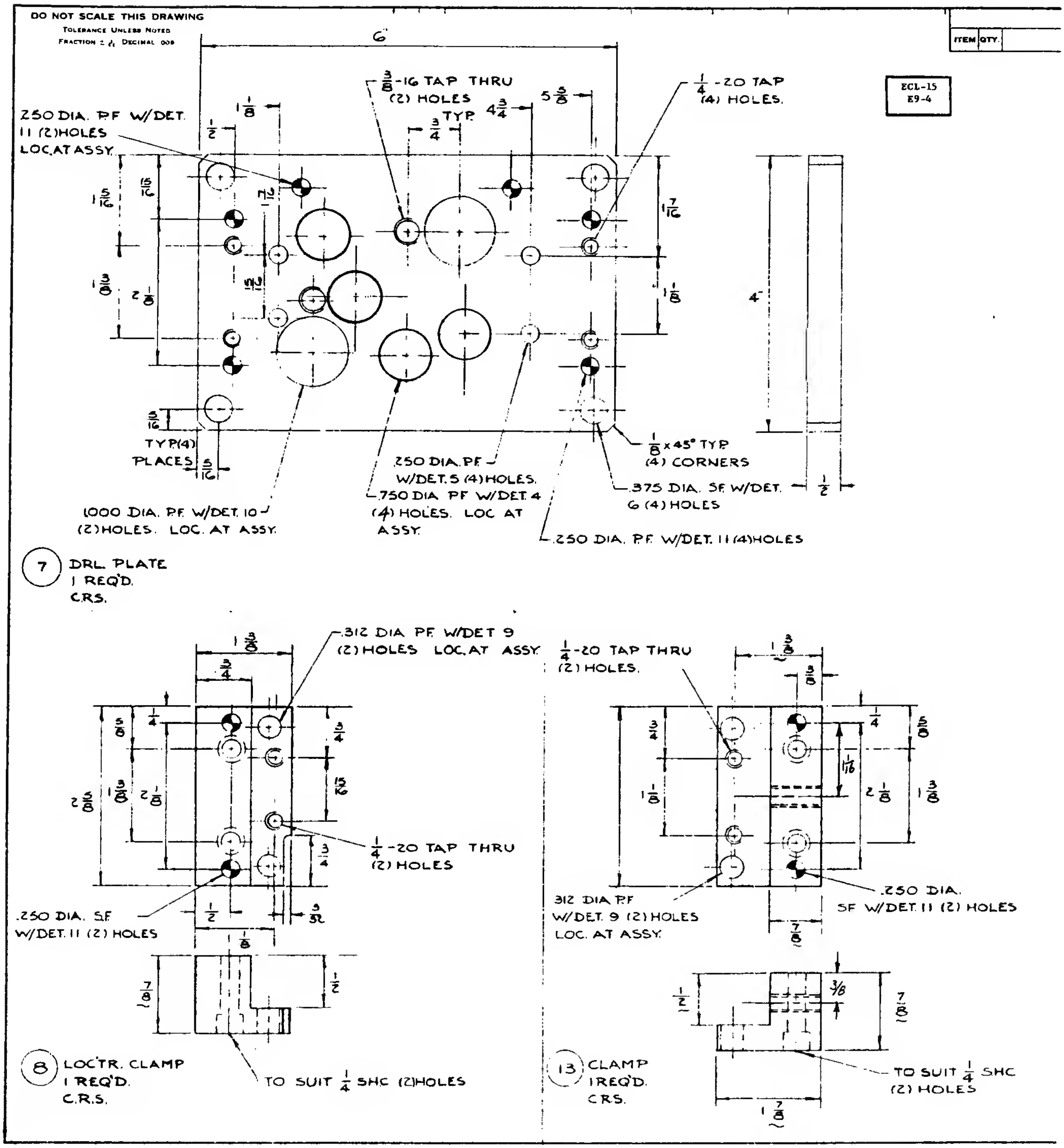


Exhibit B-5 - Drill jig detail drawings.